THE SCIENTIFIC MONTHLY

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IN NIGERIA

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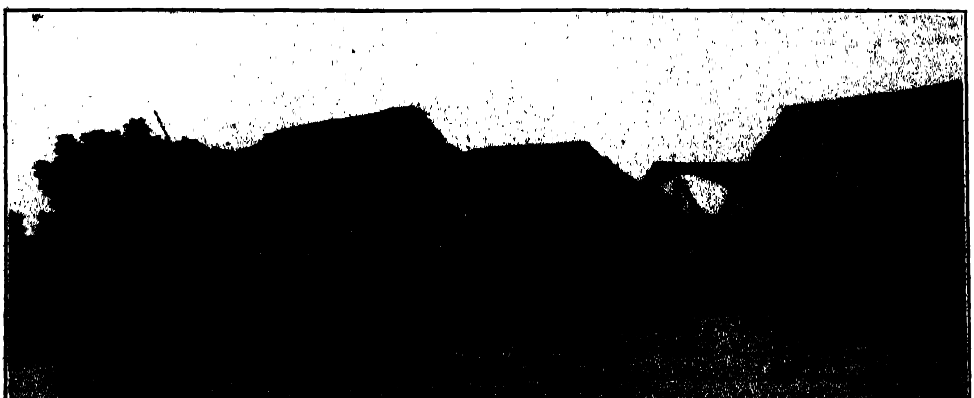
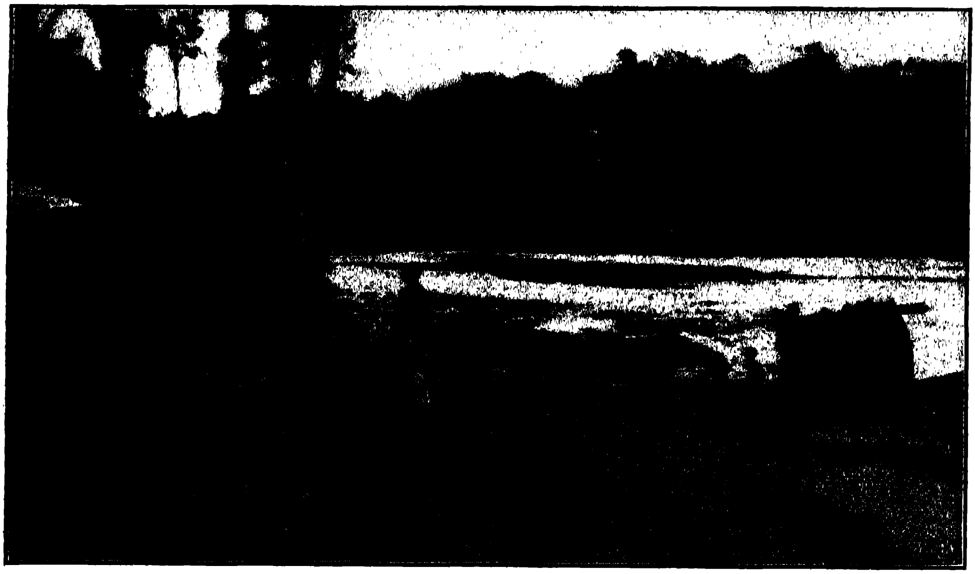
In a previous paper[1] the writer discussed the animals of Nigeria somewhat, and in this one proposes to give a brief account of the native tribes, their distribution and customs. Probably most persons look upon Nigeria as a wild country inhabited by savages. This view is proper to only a limited extent. The country is in places uninhabited and wild, but the people, though they are primitive and though some of their customs may appear to a Caucasian terrible and savage, have a folk lore, arts, and traditions which date back hundreds of years.

Disregarding minor tribes, it may be said that four races dominate Nigeria. In the Southwest live the cheerful, friendly Yorubas. These Negroes have well-organized tribal and national governments which are presided over by an Alafin, who is elected by the chiefs. The slaves of the old days came in part from among these people. In the Southeast in the general region east of the great Niger delta are the Ibos—a race which has its life centered about scattered, more or less independent villages and has no central government and no generally accepted system of laws. Most of the North is inhabited by the negroid Hausas, but the Kanuri, who are of Berber extraction, occupy a considerable area in the East. Both these tribes have long been ruled by Fulani emirs, Semitics who probably came originally from Egypt, conquered the tribes in Northern Nigeria and mixed with them. Over all the natives a handful of British administrators exercise wise and helpful control.

[1] The Scientific Monthly, Vol. 25, pp. 228–239.



A YORUBA FISHING VILLAGE

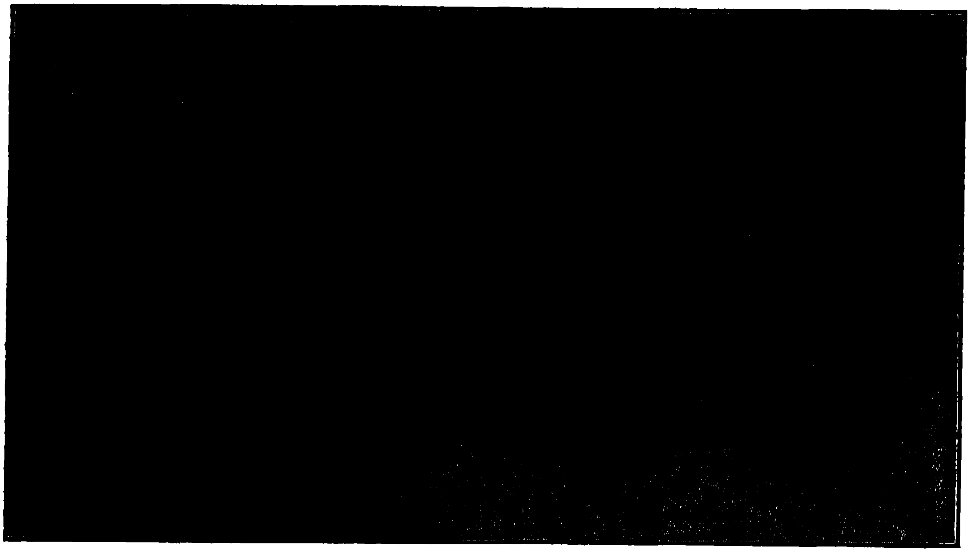


A FORD

These men are leaving the country as it is, but continually improving it. The natives retain their own customs, laws, and tribal usages, but are able to have increasing opportunities in the way of education, highways, trade, and better standards of living.

Along the coast fishing is an important means of livelihood. The natives of all coastal tribes are skilful in the manufacture and use of cast nets, fish traps and dug-out canoes. They commonly prepare fish for food by boiling or roasting on a spit. On account of diseases carried by tsetse flies there are no large animals in Southern Nigeria. The natives keep goats and sheep, and also commonly supplement their larders with rats, mice, squirrels, land snails, crabs and shrimps. Cassava is the staple carbohydrate food.

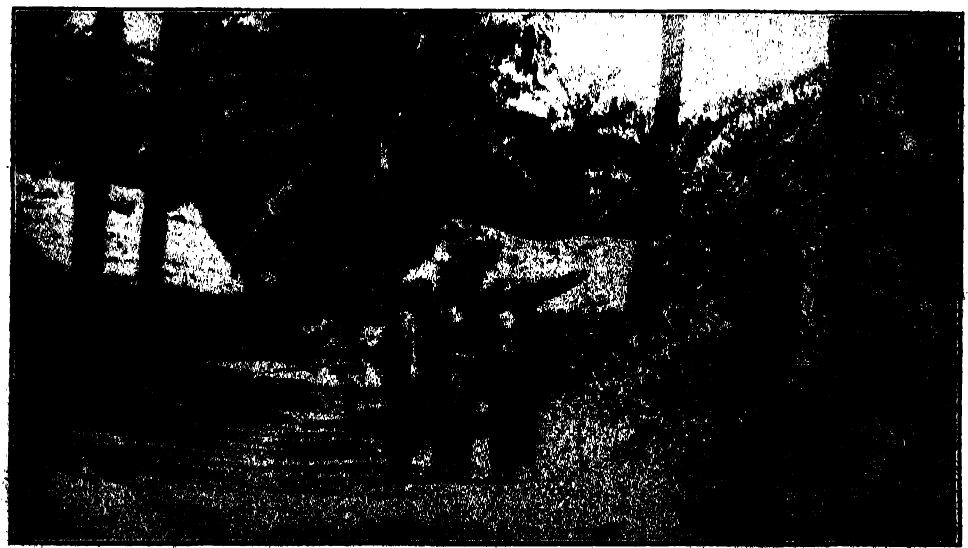
USING A CAST NET



A NATIVE PATH

A variety of fruits are raised but are not commonly eaten by natives.

The rivers are important highways. Rafts of timber are floated down to the coast. Trading canoes are sailed and poled along the extensive coastal lagoons and up and down the rivers. The Nupe tribe handles most of the native transportation on the Niger. On land there are automobile roads connecting the large cities and trade centers, but most of the natives walk over well-kept footpaths and carry their burdens on their heads. In the North donkeys, horses,



PATH LEADING TO A VILLAGE. NOTE THE DRINKING POTS FOR DEVILS ON THE RIGHT

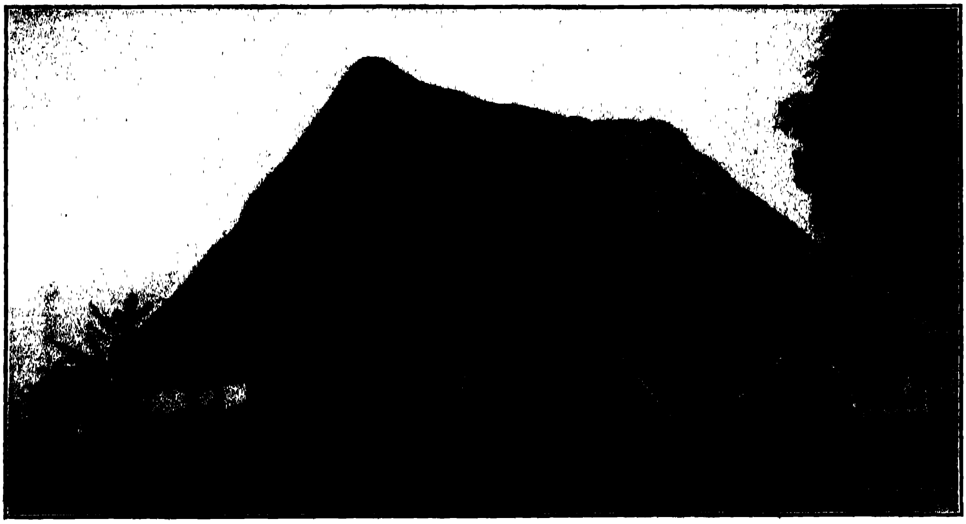
bullocks and camels are commonly used as beasts of burden. On the roads ply Fords, Reo jitneys and smaller numbers of several types of European cars.

Though the workmanship is often crude, the natives are skilful artisans. For centuries the Negroes on the Bauchi Plateau have smelted iron and the smiths have worked it into swords, hoes, axes and other articles. At Bida there are organized guilds which do excellent work in wood, textiles, brass and other metals. Benin was formerly famous for cast images, statues, and *bas reliefs* in metals and wood. Some very worthy work is still done there. In Kano and other northern cities, beautiful leather work is manufactured—pillows, bags, saddles, scabbards, shoes and other objects.

Land tenure is peculiar in Nigeria. The government owns all the land, which is assigned to kings, and these in turn allot it to sub-chiefs, headmen of villages, and finally to private citizens. The plough is not used in Nigeria. In the North the soil is too hard before planting time and in the South the presence of the tsetse fly diseases precludes the possibility of keeping large animals. All the fields are broken up by hand with hoes and mattocks. Among the natural resources of Nigeria the palms take first rank. The most valuable species do not extend far inland. They furnish oil, nuts, wine, fibers, building materials and poles for propelling canoes.

YARN DRYING

The houses throughout Nigeria are of mud. In the South they are mostly rectangular with thatched roofs, but along the Niger and northward they are commonly round. In the cities of the North, Arab architecture prevails and flat-topped, box-like houses are common. The exteriors and interiors of many of these are beautiful. The roofs are often supported by ornate pillars and arches. In making a Nigerian house the usual procedure is to plaster a framework of poles and twigs with clay. The wooden parts are commonly attacked by termites, which may work in the walls and roof of a house for years. Houses usually contain little furniture. Cook-

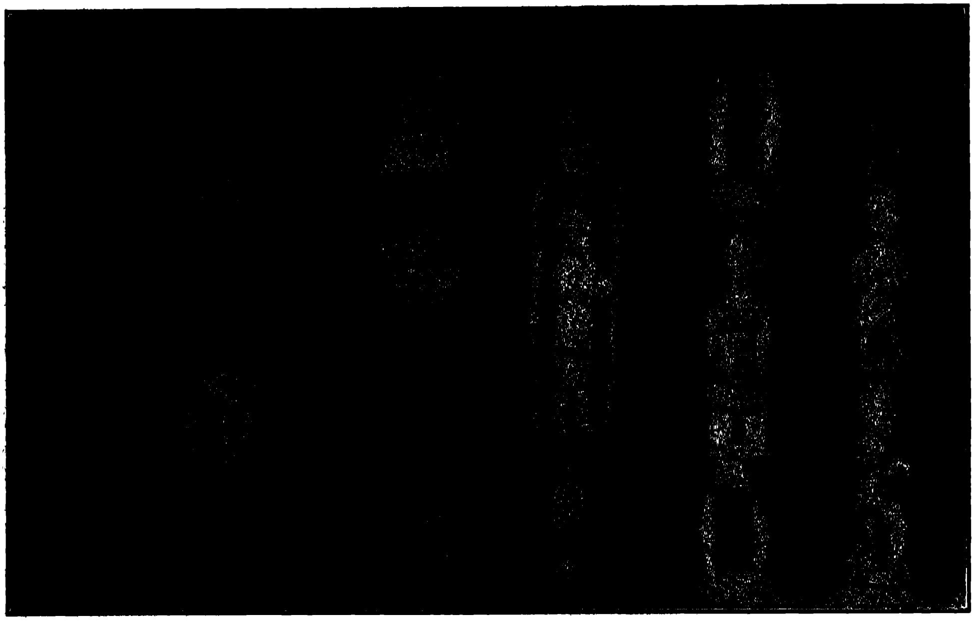


A REST HOUSE. THERE ARE NO HOTELS AFTER ONE LEAVES THE COAST OF NIGERIA

ing is done over an open fire or on a pottery stove—in a kitchen, under a porch, or in the yard. There are usually only a few chairs or stools in a village and those who entertain distinguished guests borrow from the headman. The natives commonly sleep on the bare floor or on a rush mat, but a few have bamboo couches. During meals a family usually squats about two or three dishes on the floor and fingers are the only tools used. Most of the Nigerian natives are very cleanly. The yards about the houses and paths are swept by the women or children every day, and where water is available daily baths are usual.

There are some very interesting cities in Nigeria. Lagos (100,000) is the chief seaport. It is a curious mixture of the primitive and specialized; frankly stolid native and cultured European. On the streets there are Mohammedans in turbans and long gowns, naked children, natives clad only in a piece of Manchester cloth or in frock suits, soldiers, police, sailors, goats, chickens, flocks of

A PAGAN TEMPLE

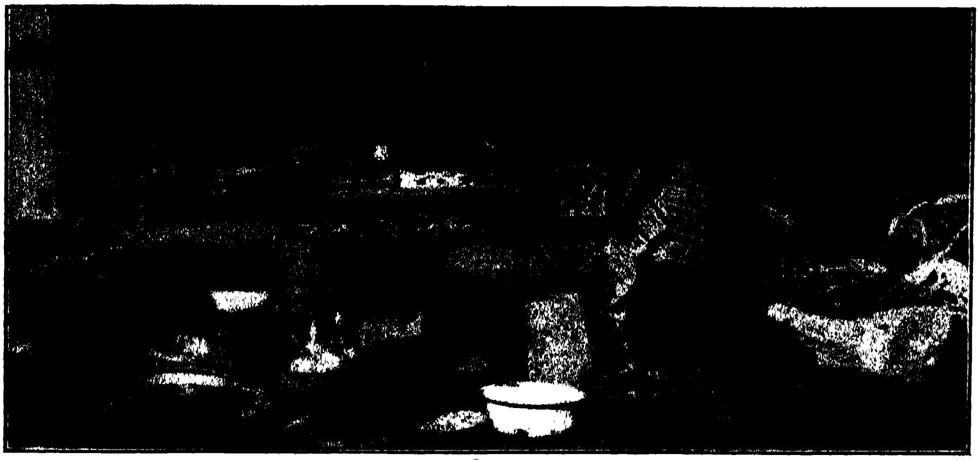


THE IDOLS IN THE TEMPLE AT IBADAN

turkeys and other animals. Half naked carriers with great burdens on their heads mingle with primitive carts, modern trucks and passenger automobiles. A modern drugstore stands near a pagan temple containing wooden idols, and along the street a little way is a mosque. There are many ju-ju shops where all sorts of charms are sold. Lagos is nevertheless a modern city with traffic police, running water and electric lights.

Ibadan (250,000) is the largest native city in Africa. It is in the guinea-grass country and consists almost wholly of mud-thatched houses. There are large, well-regulated produce markets where

THE SACRED CROCODILE AT IBADAN



A JU-JU SHOP IN LAGOS

most of the natives buy their supplies. There is a great pagan temple where gigantic wooden idols stand in solemn rows. In there a wily priest sells ju-jus. These pretty well cover all fields of human desires. A man can buy a charm to assure love, children, death of an enemy, escape after committing robbery (a very high priced ju-ju, but said to be very potent), etc. Perhaps the most unique sight in Ibadan is the sacred crocodile—a great bloated creature which lives in affluence within a mud wall. It is said that his saurian highness was, until the British stopped the practice a few years since, fed on babies. The natives believed that if one of a pair of twins was thus consumed, its surviving mate was assured of greatness, wealth and happiness, and that more or less of this success would spread to all the relatives of the eaten one. Perhaps the twin-feeding is still carried on secretly at times, but the crocodile is

A NATIVE CHIEF WITH HIS FAVORITE WIVES AND MEMBERS OF HIS COURT

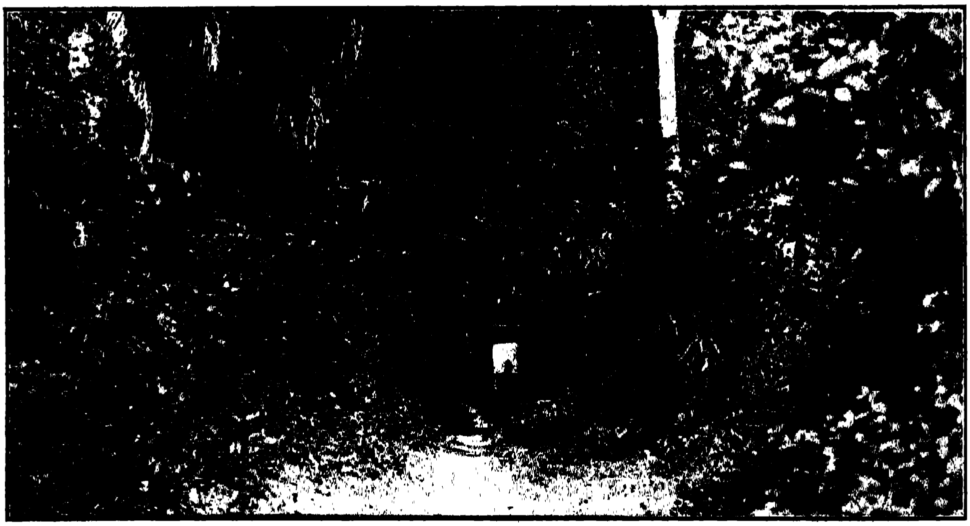
now obliged to subsist largely on living chickens, which his priest keeps on hand and condescends to dispose of to the general public for a consideration.

At Ife the six sons of the great god, Enferme, are believed to have descended from heaven and founded the six tribes of the Yoruba Nation. There is a cult of priests who observe ancient rites and have a considerable equipment of very ancient idols. A great polished monolith is said to be the tip of the staff of the warrior god, Oranyan, who left the earth in disgust and returned to heaven.

Empire set its face against slavery in 1807; and in 1852 negotiated a treaty which abolished the shipping of slaves from Lagos.

Of all the cities in Nigeria, Kano is most interesting and picturesque. A wall that is twelve miles long and forty feet thick surrounds the old city. The houses are largely of Arabian style. The camel caravans from all West Africa center at Kano. Two flat-topped bluffs and a great mosque overlook the city.

The natives of Nigeria are remarkable for their courtesy. This is true of their



ENTRANCE TO A WALLED YORUBA VILLAGE

Oyo is the home of the Alafin of all the Yorubas, the greatest king in Nigeria. In order to keep up his dignity, he maintains a harem of something over seven hundred wives, which are housed with other members of his court in a "palace." Associated with the court are a number of eunuchs and other slaves. In Nigeria there are no longer caravans of slaves chained together and driven about for sale as in the old days, but a man may, to liquidate his debts, privately sell himself or his children into slavery, or children may be kidnapped and surreptitiously sold. The British

relations among themselves as well as of those with strangers. They have formal and often elaborate social procedures. Two natives meeting on a lonely trail as they pass ask a number of customary questions concerning the welfare of wife, house, children, finances, crops and other rather personal matters which would not be mentioned in polite society by white men. A man who meets his old mother falls on his face; one who meets his cousin bends one knee. A fellow who meets a king falls on his face, throws dust on his head, then creeps forward and repeats the performance three times.

—*Photo by V. Galasounof*

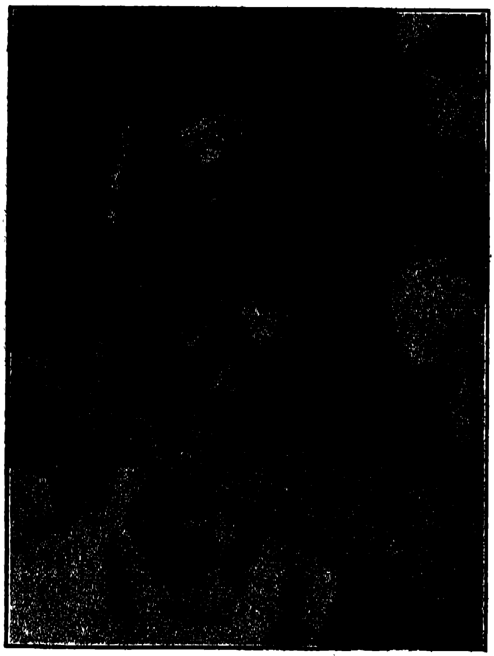
A WEAVER

YORUBA WOMEN

He is expected to remain flat on his belly throughout his audience and back away, bowing, when he leaves.

The African natives are fond of games and amusements. Iu is a game which is quite widely distributed in Africa. It is played by two or more persons who move seeds from hole to hole in what looks like a wooden muffin pan, or, if better equipment is lacking, play by moving stones about in holes in the ground. Another sport is sort of a masquerade. A few young fellows in a village put on costumes and suddenly appear in the public square of some neighboring village, where they go through more or less farcical or allegorical mummeries. Some mummers are rather professionals and travel about the country from one festival to another. It is important that the identity of the maskers remain unknown and they therefore go completely covered, with gloves and leggins. In the North the Hausas and Fulanis keep some fine horses and are very fond of racing. Cock fighting is also a popular sport.

A YORUBA MAN AND WOMAN IN THEIR BEST CLOTHES



—*Photo by V. Galaounof*

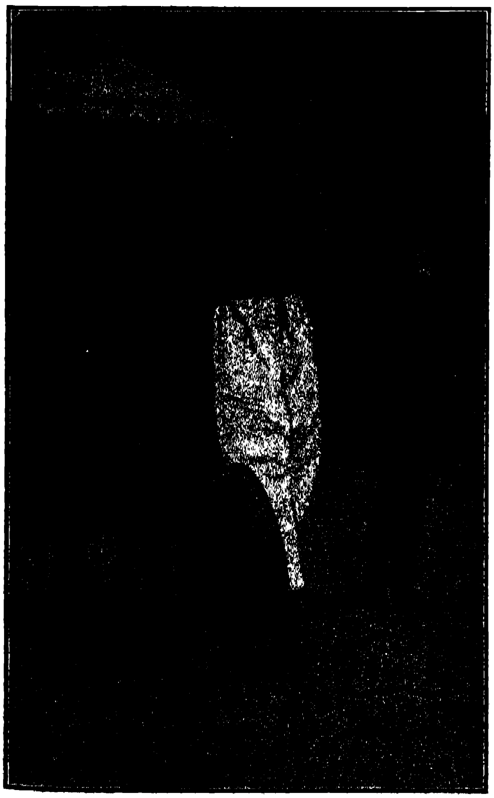
MAKING A FISH TRAP

Though there are several types of native instruments, even including primitive violins, most of the music is furnished by drums. The West African drums are elongated and the strings around the sides are so arranged that the drummer may tighten or relax them as he plays. The drums not only make rhythmical music for dances but are also used to imitate the sounds of the human voice. The largest drums can "telegraph" messages for many miles.

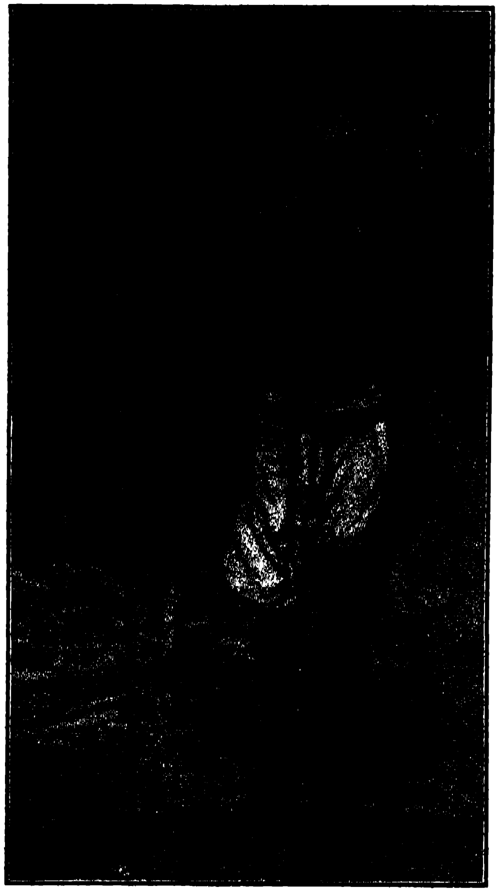
Women in Nigeria always hold subordinate positions and spend most of their time working at rather arduous household duties. They gather crops, crack palm nuts, carry water, wash, make meal, and take products to market and sell them. The men do the more

dangerous and difficult tasks, such as fishing, hunting, hoeing and climbing palm trees. A man when he marries, always buys his wife—for from $100 to $300. A wealthy fellow has few ways of showing his affluence and usually buys a number of wives. The ambition of a middle class man is to be able to buy two or three wives, who will largely support him by their labor and thus permit him to live a life of ease.

The Hausa traders travel singly or in small groups throughout West Africa. They walk hundreds of miles each year, carrying their packs on their heads. They are usually armed with a sword, spear, or some other weapon. Squatting in the door-yard they display leather work from Kano, brass from Bida, images from Benin, marabou stork feathers from the Sudan, carved ivory



A VILLAGE MEDICINE POT

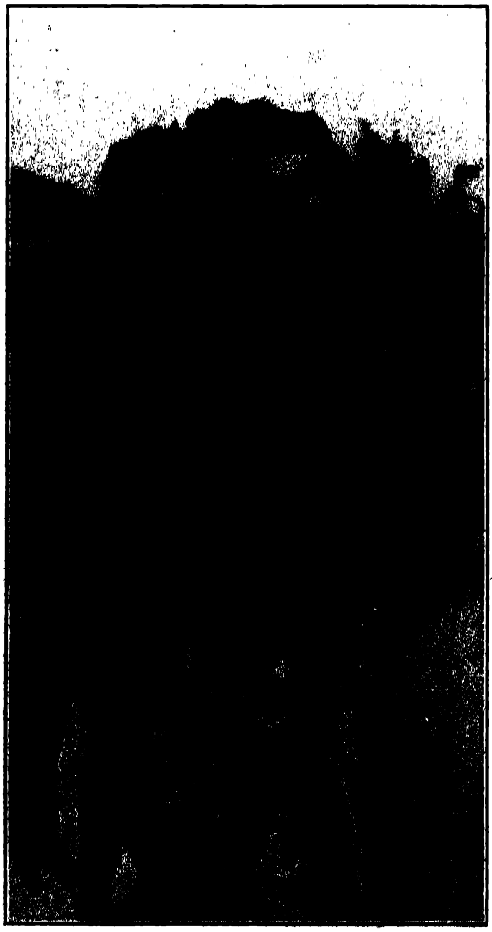


A FARMER BESIDE A BEAN POD WHICH IS PLACED AT THE EDGE OF A FIELD TO KEEP AWAY THIEVES

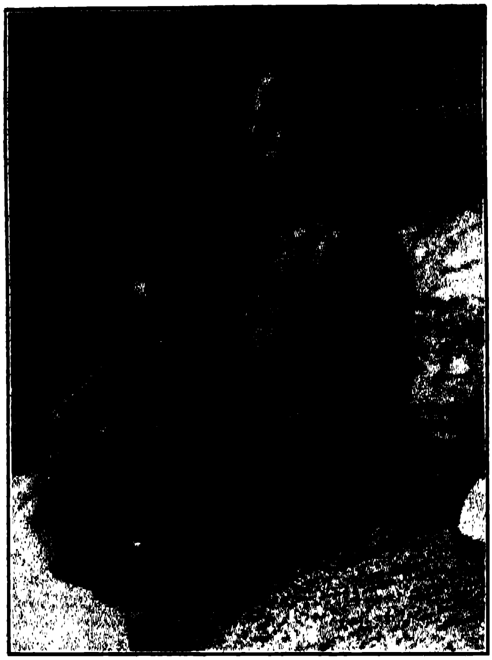
from Calabar, horns and skins from the game country, and other treasures. They tell monstrous and not very artful lies about their wares. They have endless patience and you finally buy in spite of yourself.

In Nigeria belief in devils, fetiches and charms is nearly universal. Most native men have from one to half a dozen leather covered charms tied to their belts. At each fork of a native trail a pot of water is kept, and perhaps also some food is scattered about. Often these offerings are set on a little mound in a cleared and swept space and at times ever covered by a roof, or devil

house. The pot enables the devils to drink as they wander about at night, and they are thus less likely to visit the neighboring villages. Farmers commonly place large bean pods around their fields at the tops of sticks. These are believed to work evil to any one who steals from such a field. One day I walked along a trail with my boy, Rufus, who could read and write in an illiterate fashion and spoke fairly good English. I saw a fallen palm with a hole in its butt and asked Rufus what lived in it, supposing he would give me



MOTHER AND A CHILD WITH AN UMBILICAL HERNIA, WHICH IS QUITE COMMON



THE PUBLIC BATH

the name of some animal, but he answered:

Devil, Sar.
What kind of a devil?
Many devils, veree small. He come at night. No hurt nothing.

During my months in Nigeria, I learned much of the habits and tastes of devils. The natives speak of them as natural concomitants of daily life.

Nigeria, especially near the coast, is probably as unhealthy as any country in the world. Plague is endemic for a hundred miles inland; yellow fever is sporadic but perennial; malaria is common and often followed by blackwater fever; several species of filarial worms live in man; sleeping sickness is inoculated into people by tsetse flies; relapsing fever is spread by ticks and lice. Besides diseases, there are numerous biting flies, ticks, fleas and other small vermin. The female chigger flea has a habit of burrowing under a man's toenail where,

A DEVIL HOUSE

WALL ABOUT A YORUBA VILLAGE

after a time, she grows to the size of a pea and produces a brood of eggs.

Nigeria is a fine example of a pioneer country with rich potential resources. When the diseases are controlled or eradicated it will still be a place for short tours by white men, for the climate is trying. At present the primitive peoples are largely unspoiled by contact with commerce and civilization and offer good material for scientific study. The British are exercising a very wise colonial policy—the traditions, laws and customs being changed only when they seriously interfere with the progress of the country.

A DUG-OUT CANOE OFF SIERRA LEONE

WILD LIFE IN LOUISIANA[1]

By PERCY VIOSCA, JR.
STATE BIOLOGIST OF LOUISIANA

THE mere mention of natural history in connection with Louisiana is suggestive of something different, something primitive, of a wild life varied and unique in a region of jungle land and dismal swamp almost impenetrable. It calls forth thoughts of the mighty Mississippi depositing almost unhindered in its great delta the most fertile soil taken from two thirds of the area of the United States, and thereby giving birth to marshlands of vast extent, followed later, as more sediments are deposited, by cypress forests, which in turn give way to hardwood glades as their level rises higher above the sea.

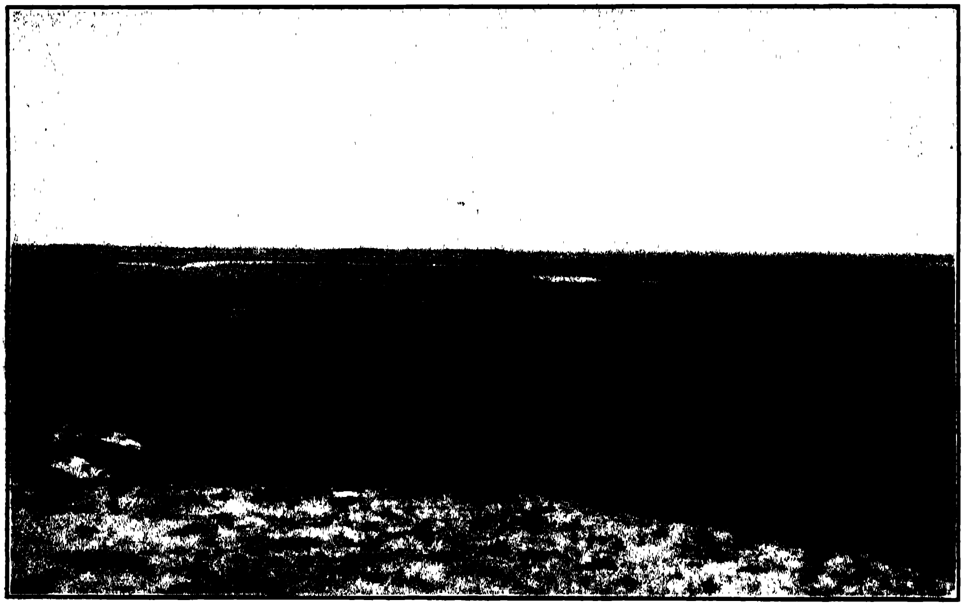
Of the wooded wet lands there are over two million acres; in these wet lands the shallow waters are protected from the rays of the sun by the dense foliage of the towering cypress and tupelo gums, which have their branches festooned with Spanish moss.

Forming a network through the swamps and serving as their natural drainage channels are deep winding bayous, some cypress bordered, some paralleled by low-lying ridges of land. The ridges, which at most are only a few

[1] One of the Smithsonian series of radio talks arranged by Mr. Austin H. Clark and broadcasted from Station WRC, Washington.

BARATARIA BAYOU

BORDER OF CYPRESS, WITH A HARDWOOD GLADE IN THE BACKGROUND.



A TYPICAL COASTAL PLAIN MARSH

SEVEN MILES SOUTHEAST OF SLIDELL, LA.; HABITAT OF *Rana grylio* (IN THE OPEN LAGOONS) AND *R. sphenocephala* (ON THE EDGES).

A MIXED SWAMP

IN THE PEARL RIVER VALLEY, NEAR THE MOUTH OF BOGALUSA CREEK.

GRYLIO POND

IN THE PEARL RIVER VALLEY; A LAGOON IN A SWAMP—THE ORIGIN OF A GREAT FROG CHORUS.

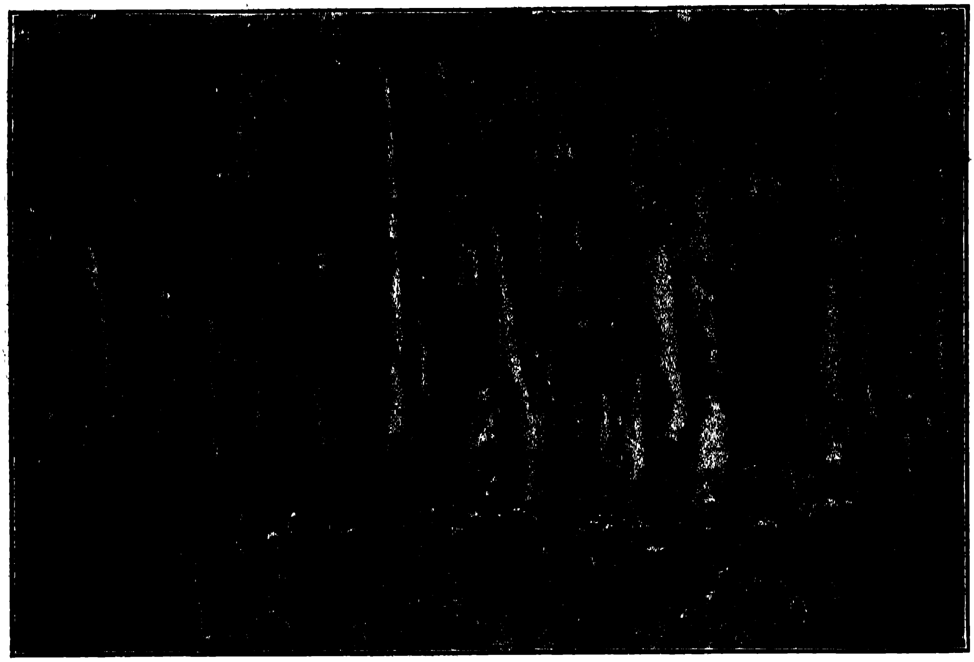
feet above sea-level, are dominated by gigantic live-oaks, which also are beautifully draped with the gray swaying mosses. Impenetrable cane-brakes and dense thickets of dwarf palmetto make up the dominant undergrowth.

Sections of the former Gulf of Mexico now almost surrounded but not yet completely filled in by the sediment from the river form the tide-level fresh-water lakes of this interesting region.

A total of ten million acres, or approximately one third the total area of the state, is included in this tide-level swamp, marsh and lake region of Louisiana. It is here that we find the richest wild life in the state, if not, indeed, in the entire country. Rich both in number of different kinds and in number of individuals, water-living and woodland forms of animals and plants are freely intermingled.

It is here that we find the last stand of the American alligator, which is at home alike in the marshes, swamps, lakes or bayous. We may see them basking on a shelf along the shore of some lagoon or bayou in the winter or spring sunshine. They retire to their subaquatic tunnels only during cold weather. During the remainder of the year they are difficult to observe by daylight; but after dark their fiery red eyes shine brilliantly by reflection from an acetylene light worn on the head, appearing as balls of fire in the inky blackness.

The alligator is unique among the American reptiles in regard to its breeding habits. The female builds a nest of rushes, sticks and decaying vegetation mixed with humus, and in this places her eggs, which number about sixty. The heat from the sun and the heat given off by the decaying vegetable matter incubate the eggs, which hatch in August and September. The baby alligators, which are about seven inches long, are assisted by the mother in escaping from



EDGE OF A TUPELO SWAMP
WITH BLUE FLAG (*Iris*) IN THE FOREGROUND.

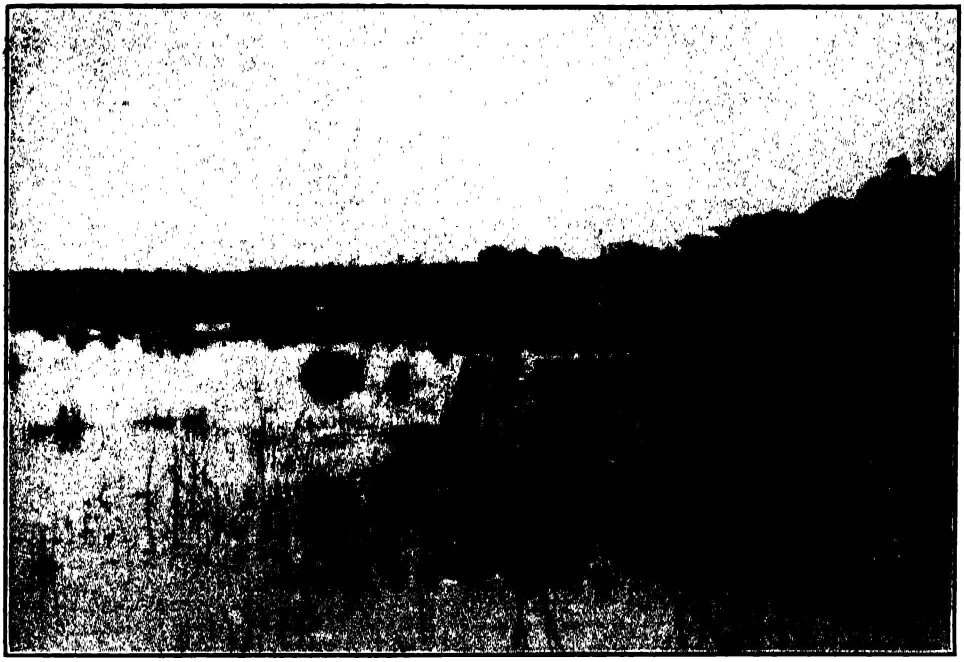
the nest and are carefully guarded by her for about three and a half years, most of them wandering away during the fourth spring, when they average about four feet in length. There are, therefore, from three to four generations of young alligators living more or less amicably together and having their home in their mother's burrow. Although the mother alligator will fight to protect her young, which is not the case with any other kind of American reptile, statistics show that there is far less danger in hunting baby alligators than in being an ordinary pedestrian.

Another monster of this region which is partial to the fresh-water lakes and bayous is the so-called alligator snapping turtle, which weighs upwards of 150 pounds. Unlike the common snapper it is a docile creature. It seems to attract fish into its razor-like jaws by wiggling a worm-like lure on the end of its tongue. The smaller, though actually more formidable, common snapping turtle shows a preference for the shallower waters of the swamps and marshes.

Other kinds of fresh-water turtles are also seen in great abundance, and the water-moccasin and a host of water snakes are ever present.

After a visit to the lowlands of Louisiana you can never forget the tremendous chorus of the male amphibians, the frogs and toads. Of the twenty-four kinds of frogs and toads found in the state not less than eighteen are found in or near the swamps and marshes, and some of these greet you at all seasons of the year. Three kinds are at their best during the height of winter, depositing their eggs even before Santa Claus' annual visit.

Represented in the nocturnal chorus of the amphibians are various imitations of trumpets and other holiday noise-making devices, electric buzzers, sounds



TRANSITION FROM MARSH TO FOREST LAND
HARDWOOD GLADE ON THE RIGHT AND PINES IN THE BACKGROUND.

like the static on your loud speaker, ropes drawn through pulleys, lost chickens, distant cow-bells, sleigh-bells, machine hammers, whistling notes, resembling those of the red-bellied woodpecker, and other noises recalling the sounds of barking dogs, ducks, gallinules, banjos and ukeleles. The southern bullfrog of the open lakes and lagoons sounds like a herd of swine, while the giant bullfrog, the bandmaster *par excellence* and the leader of the chorus, sometimes thousands of individuals together, sounds like so many bellowing bulls.

We must not neglect the smaller creatures of the swamps. Chief among these is the southern red crawfish, the chief food of the bullfrog, the amphibious congo eel and of most of the fresh-water game fishes of the bayous of the region. The red crawfish of the Louisiana swamps is considered by some epicures as the greatest of all known delicacies, in comparison with which the famous Atlantic lobster appears quite tasteless.

For those who crave excitement there is plenty here. The tangled undergrowth of the cane-brakes is the refuge of the Louisiana black bear, the bob-cat, the white-tailed deer and a gigantic race of the timber rattlesnake. More conspicuous, though less forbidding, are the live-oak snake, which is a race of the chicken snake, the American chameleons, the blue-tailed skinks or lizards, the gray squirrel, the raccoon and the opossum, and the cardinal and a host of other small birds.

In the marshes of the state, which were formerly considered as waste lands, we have our most valuable wild life areas. Foremost among the fur-bearing animals is the muskrat, which produces some five million dollars' worth of raw pelts annually. Mink and otter are also

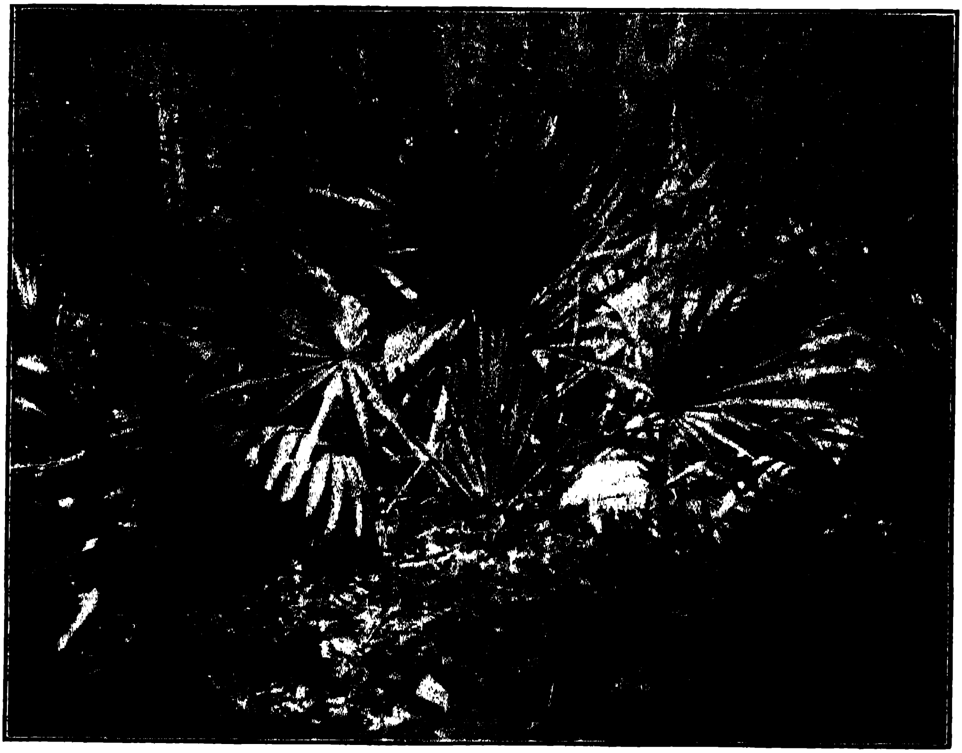
AN ALLUVIAL RIDGE
TRAVERSING A SWAMP IN ST. JAMES PARISH, LA.; HABITAT OF BLACK BEAR AND DEER.

plentiful. The marsh hare is in evidence everywhere and is a most important source of food and recreation. Ducks of many kinds are abundant in the numerous lagoons which dot the marshes, while geese abound on the exposed flats and beaches of the coastal islands.

As we go toward the coast, or away from the mouths of the great rivers, it is interesting to observe how the fresh-water life is gradually replaced by that of the salt-water. The salt marsh-water snake replaces the fresh-water snakes, while the valuable and justly famous diamond-backed terrapin replaces the fresh-water turtles. The southern leopard frog and the southern bullfrog can tolerate a limited amount of salt, but as soon as the salt becomes noticeable, crabs, fiddler crabs and salt-water mollusks take the place of the fresh-water life.

A similar transition takes place in the strictly aquatic animals of the tide-level lakes as we approach the sea. Fresh-water shrimps, fish and mollusks and certain brackish water kinds are at first found side by side, but near the sea-coast fresh-water types give way entirely to marine life, and we find ideal conditions for the growth of the oyster, the blue crab, the large edible shrimp, the menhaden and a long list of food fishes.

In speaking of our marshes, we should point out that their greatest value is as sources of food supply for the great variety of valuable creatures that live in the bays and lakes near the coast. The tons of soil, rich in nitrogen, which are annually deposited in our marshes by the rivers, support a luxuriant growth of rushes, grasses, sedges, reeds and cat-tails as well as of under-water plants. These not only serve as a basic food for

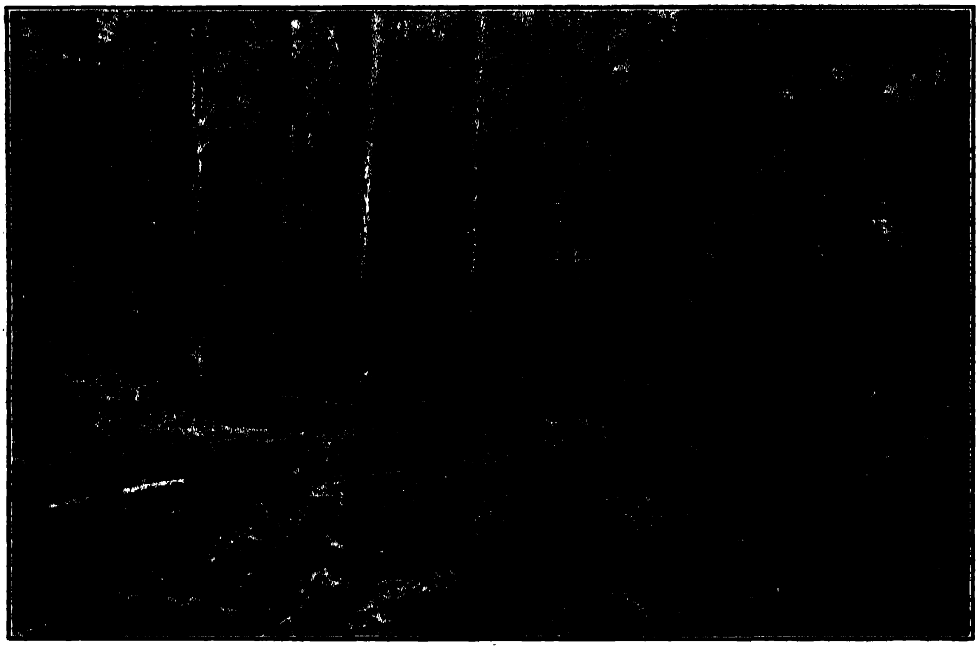


DWARF PALMETTO AND CANE BRAKE
GENTILLY RIDGE, TEN MILES EAST-NORTHEAST OF NEW ORLEANS, LA.

the birds and mammals, but also for the small shellfish, crustaceans and worms which, at the falling tide overflowing into the deeper waters, serve in turn as food for the fishes. The bits of vegetable matter which are washed into the lakes form the direct source of food for our valuable salt-water shrimp, the Louisiana coast producing more edible shrimp than all the rest of the United States together. Again, the food of the oyster is developed largely in the marshes, the receding tidal waters carrying seaward over the oyster beds vast quantities of those minute plants from which they derive their sustenance.

Strange as it may seem, the swamp and lowland region of southern Louisiana is entirely free from malaria, and our permanent wooded swamps are free from mosquitoes.

The seacoast life of Louisiana is varied and interesting. It differs materially from that of the other coastal states owing to the absence of coarse sand or hard rock bottoms and to the presence of soft muds and clays deposited by the rivers. The water is never absolutely clear, for fine sand and silt are always present in suspension. Seaweeds and animals which attach themselves find it difficult to obtain a foothold. Starfishes, sea-urchins, lobsters and rockweeds are absent. On the other hand, creatures that burrow in the sand or mud are abundant, and we have a great variety of worms, shellfish and crustaceans.



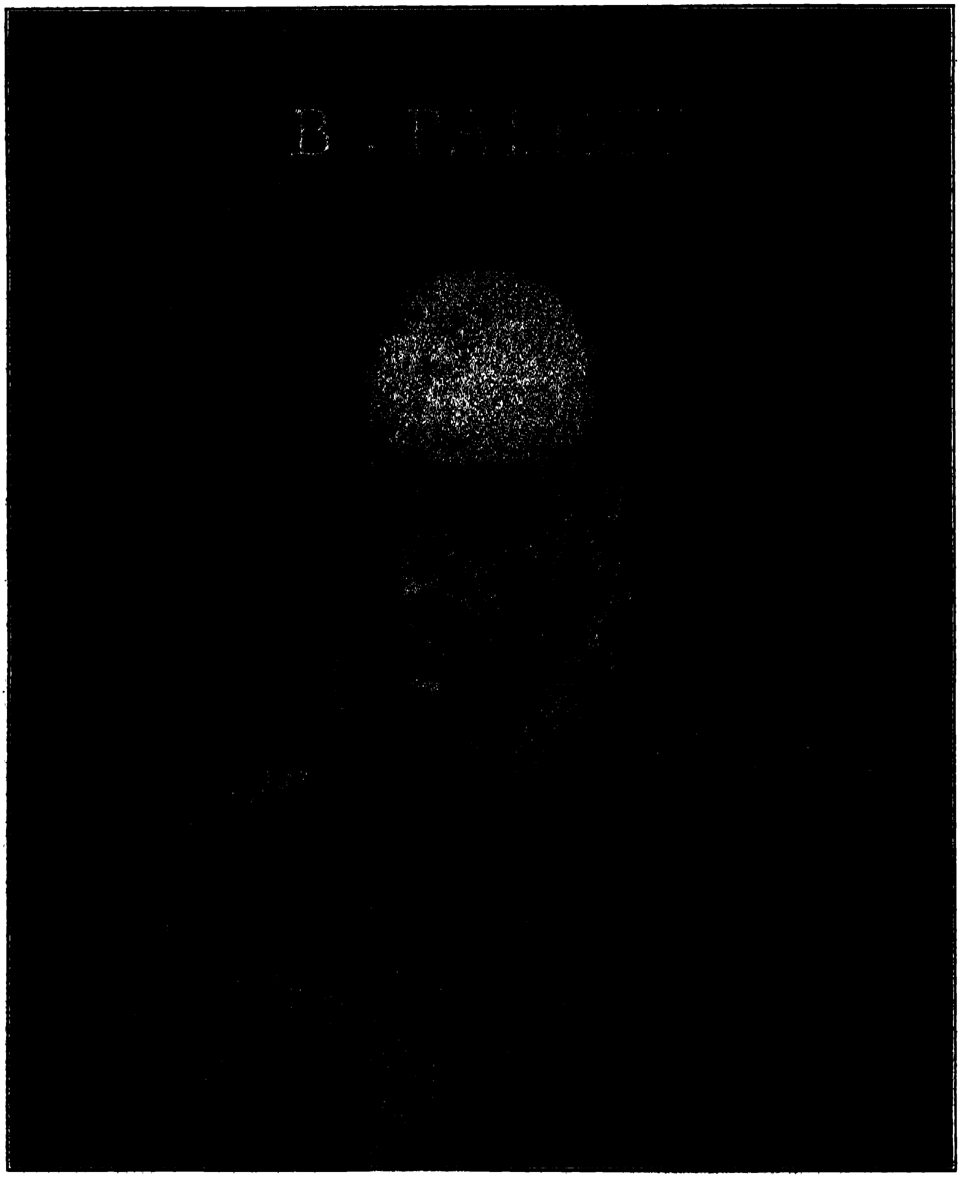
MIXED FOREST
OF PINE AND HARDWOODS ON THE PINE FLATS NEAR PEARL RIVER, LA.

AN OAK RIDGE
WITHOUT UNDERGROWTH ON THE COASTAL PLAIN; THE OAKS ARE FESTOONED WITH SPANISH MOSS (*Tillandsia*).

Among the larger things in the coastal waters are the green sea-turtle, the giant logger-head, weighing sometimes as much as five hundred pounds, a large variety of sharks, the saw-fish, the tarpon or silver king, dolphins and the giant devil-ray or manta, weighing several tons. The catching of this last is considered the climax of sport.

In northern and central Louisiana we have several great river valleys and dry lake bottoms with extensive hardwood glades. We have a bluff formation composed of a light powdery soil and also characterized by hardwood forests. In southwestern Louisiana we have an extensive prairie or grassland region with its typical prairie life. Both in east and west Louisiana we have extensive flat or rolling pine lands traversed by clear sandy or gravelly spring-fed streams. Here live the cotton-tail rabbit, the fox squirrel, the gray fox and the timber wolf, the wild turkey and the bob-white, while the woodcock and other upland migratory birds winter in great numbers.

We also have other sorts of regions in Louisiana, but I have said enough to indicate to you how varied and interesting is the wild life of the state and also how different it is from the wild life in other states.



AGRICULTURAL OBSERVATIONS OF BERNARD PALISSY, THE HUGUENOT POTTER

By GRACE M. ZIEGLER

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At a time when much of scientific belief was founded on conjecture and when education was thought to be for the rich, Bernard Palissy, the son of a poor workman in glass, attained distinction as an artist, potter and naturalist. Although his name is chiefly associated with his pottery work, his "pieces rustique" and other ware being valued at excessive prices, his conclusions in the field of nature won for him an outstanding place among the naturalists of the sixteenth century. His theories on agricultural practice, as told in his discourse on "How to grow Rich in Farming" and in other writings, show the accuracy of his observations and have earned for him a place among the earliest leaders of scientific agriculture. His perseverance throughout a period of direst poverty and in spite of the reproaches and ridicule accorded him by his acquaintances and even by his family while experimenting in the making of enameled ware, and the persecution he suffered on account of his religious beliefs, were such that, according to M. de Lamartine, "he has exercised an influence on civilization, and has deserved a place to himself amongst the men who have ennobled humanity."[1]

Born about 1509, probably in a hamlet near Agen, France, Palissy first became a glass painter. Not being satisfied with copying the patterns given him, he began as a youth to draw his own designs, preferring objects of nature and his mother's face as subjects. Having gained considerable knowledge of geometry, the natural sciences, drawing and painting, at the age of eighteen he embarked on his own career, traveling for ten or twelve years throughout France, in Flanders and on the Rhine, and adding to his store of information. That the sum total of his knowledge was acquired through observation is shown in his own words, "I have had no other books than Heaven and Earth, which are open to all."[2] In 1539 he married and settled in the town of Saintes, where he resided until he was imprisoned for heresy.

Many of the writings of Palissy are in the form of dialogue, to "procure for the discourse more ready comprehension," one person, "Theory" to inquire and "Practice" to reply. He believed it his duty to record the history of the troublous times through which his country was passing and also the knowledge he possessed on the various subjects which had occupied his attention. His love of nature is interwoven in practically all his endeavors, even his idea of creating beautiful pottery being to embellish the objects with specimens of nature—frogs, lizards, fishes, snakes, beetles, butterflies, shells and plants.

In "How to grow rich in Farming," the need for intelligence in farming is emphasized in characteristic manner: "I see so much error and ignorance in all the arts, that it seems to me as if all order were for the greater part perverted, and that each labours on the soil

[1] "Palissy, the Huguenot Potter," by C. L. Brightwell, Phila. 1858.

[2] "Palissy, the Potter," by Henry Morley, London. 1852.

without any philosophy, and all jog always at the accustomed trot, following the footsteps of their predecessors, without considering the nature or the prime causes of agriculture . . . I tell you, that there is no art in the world, in which a greater philosophy is required than agriculture; and tell you, that when agriculture is conducted without philosophy, it is the same thing as a daily violation of the earth, and of the things which she produces; and I wonder that the earth, and the natures generated in the same, do not cry vengeance against certain murderers, ignorant and ungrateful, who daily do nothing but spoil and waste the trees and plants without any consideration."

On the subject of impoverishing the soil by the extraction of potassium carbonate through cropping, Palissy was many years in advance of scientific research. His theories of replacing the salt, as propounded in the above-mentioned discourse, indicates that he had reference to potash salts. He asks, "Have you not seen certain labourers who, when they wish to sow a piece of land two years successively, set fire to the stubble or straw remaining from the grain which has been cut; and in the ashes of the said straw will be found the salt which the straw had extracted out of the earth, which salt, remaining in the field, will aid the land again; and so, the straw being burnt in the field, it will serve as manure would, because it will restore the same substance which it had extracted out of the earth." It is now well known that most of the potash absorbed from the soil by plants remains in the straw or stems and that little is contained in the grains.

To prevent the washing away of "salt" from manure by rains, he advises that a pit be hollowed, paved with flints, stones or brick, well plastered with mortar, and protected from the rains and sun by some sort of hut, for "when placed outside the stables, without any consideration," he says, "take notice in a time of rain, and you will see that the waters which fall on the said muck-heaps, carry away a black tint in passing through the said heaps; and finding the base, slope, or inclination of the place on which the heaps are put, the waters which pass through the said heaps will carry away the said tint, which is the chief part and whole sum of the substance of the muck-heap, for which reason the muck-heap so washed can serve only for a parade; but being carried to the fields, it there yields not any profit." As two thirds of the potash in manures is now known to be in a soluble condition, the best farm practices protect manure against loss from leaching by providing tight floors and shelter from rains.

A study of Palissy's reasoning with respect to salts in wood ashes is especially interesting, particularly in view of the fact that until the discovery of the Stassfurt salts in 1864, the principal source of potash salts was hardwood ashes. He says, "I venture to tell you afresh, and to maintain daringly, that there is no plant, nor kind of herb upon the earth, which has not in itself some species of salt; and tell you further, that there is no tree, of whatever kind it may be, which does not accordingly contain some of it, some more, some less. . . . Take notice of the smoke of wood; for it is so that the smokes of all kinds of wood make the eyes smart and injure the sight, and this because of certain salsitude which it draws from the wood, when the other humours are exhaled by the vehemence of the fire, which chases the hurtful and humid matters: and that this is so, you will recognize when you cause water to boil in some cauldron; because the smoke from the said water will do no harm whatever to the sight, though you present your eyes over the said smoke."

Again, he tells of some laborers who manure their fields with a kind of earth called marl, which they find of more value than dung. He promised "If I see that my writings are not despised, and that they are put in execution, I shall take pains to seek for the said marl in this region of Xaintonge, and will make a third book, by which I will teach all people to know the said marl, and even the method of applying it to fields, according to the way of those who are accustomed to its use." This pledge he afterwards fulfilled.

Especially to be deplored was the indifference of farmers regarding the tools and implements which might lighten the labor of agriculture and increase the production: "I wonder at the ignorance of men, when I look at their agricultural implements, which ought to be in more request than precious bits of armour. . . . I could wish that the king had founded certain offices, estates, and honours, for all those who should invent some good and subtle agricultural tool." These and other utterances far in advance of his time fill many pages of the potter's writings.

Palissy's persistent search for the method of making enameled pottery gives us a vivid picture of the caliber of the man. Since glass-making was practiced by many people of little skill, only a very meager living was to be obtained therefrom. His other means of livelihood, land surveying and portrait painting, were only in occasional demand. Chancing to see a beautiful Italian cup of enamel, he was inspired to make the production of enameled ware his life work, believing that his skill in drawing would enable him to produce objects of great beauty. At this time there was no enameled ware produced in Europe outside of Italy, but nothing daunted, and without knowledge of the baking of earth or of the materials of which enamels were composed, he set to work confidently to discover through experimentation the methods of its production. His family, together with his pecuniary difficulties, prevented a few trips that might have saved him many costly and disheartening mistakes. For sixteen years he bent his energy to this end, his life during most of this time being one of extreme wretchedness and poverty. Many children were born to him, all were undernourished, and six of them died. At one time he was compelled to burn the palings of his fence and his tables and flooring of his house to maintain sufficient heat to finish a trial lot. Twice he was near the verge of despair, and was compelled to turn to other employment to provide the necessities of his family. The first time he received a commission from the government to make a survey of the islands of Xaintonge and the district of salt marshes to establish the gabelle, or tax, on salt, and the second time he replenished his finances by painting.

It took Palissy about eight years to discover with certainty the process of producing white enamel, which he considered the basis for all enamels, and during the succeeding eight years he found to his surprise and sorrow that there were many other things unknown to him. Accidents befell him in many ways—ashes flew against his vessels and mingled with the melted enamels; the mortar of a furnace he built was full of flints, which burst into pieces when heated, spattering his work and becoming hardened with the enamel; his vessels were baked too much or too little, or they were baked properly in front but not baked at all behind; sometimes the enamels were put on too thinly, and sometimes they were too thick; and when there were enamels of different colors some were burnt before others had melted. There were difficulties in the choice and management of clays.

His sufferings, and his courage, are shown in occasional paragraphs of his writings. When one of his trials was about to be completed, many of his creditors came to watch the result. According to Henry Morley, "He had expected three or four hundred livres. 'I received,' he says, 'nothing but shame and confusion; for my pieces were all bestrewn with little morsels of flint, that were attached so firmly to each vessel, and so combined with the enamel, that when one passed the hand over it, the said flints cut like razors. And although the work was in this way lost, there were still some who would buy it at a mean price; but, because that would have been a decrying and abasing of my honour, I broke in pieces the entire batch from the said furnace, and lay down in melancholy—not without cause, for I had no longer any means to feed my family. I had nothing but reproaches in the house; in place of consolation, they gave me maledictions. My neighbors, who had heard of this affair, said that I was nothing but a fool, and that I might have had more than eight francs for the things that I had broken; and all this talk was brought to mingle with my grief.' "

It was during the lifetime of Bernard Palissy that Martin Luther founded the basis for the Protestant religion in Germany, and about the time Palissy succeeded in pottery-making Calvinism had gained considerable headway in France. Characteristically, Palissy set out to determine religious truth, and having reached a conclusion nothing could alter his determination to stand by it. At his instigation a group of six men, including himself, was formed to worship secretly in accordance with their belief, each taking his turn at preaching to the other five. This was the beginning of what later proved to be a large congregation of the Reformed Church at Saintes. Palissy describes the horrors of this time, when first the youth, Charles IX, and later his brother, Henry III, became king of France, but their mother, the treacherous Queen Catherine de Medicis, was the actual ruler. There were two political factions, one headed by the Duke of Guise, who was the leader of the extreme Catholic party, and the other by Constable Montmorenci, of more liberal tendencies, with the Queen endeavoring not to offend either party but to hold them so well balanced that she might sway either as she pleased. Although heretics were constantly being burned to death, Palissy believed himself safe because of the interest of his friend and patron, Montmorenci, who had issued orders that the artisan be protected. However, in 1562, he was imprisoned at Bordeaux, but was released on the plea of the Constable by Queen Catherine, whose redeeming trait seemed to be her interest in art and literature. The potter was appointed by her as "workman in earth to his majesty," his task being to adorn the gardens of a new palace, the building of which was then engaging the attention of the queen-mother.

While engaged in this work and in pottery-making in Paris, Palissy decided to test his theories on agriculture, chemistry, mineralogy and geology by subjecting them to criticism. This he accomplished by delivering in his own museum, over a period of nine years, the first series of lectures on natural history ever given in that city. To secure the most intelligent audience he charged a dollar admission, knowing that if he spoke falsely "there would be Greeks and Latins who would resist me to my face, and who would not spare me, as well on account of the dollar I should have taken from each, as on account of the time I should have caused them to misspend." He adds, "Thanks be to God, never man contradicted me a single word." His audience consisted of

"many skilful physicians, celebrated surgeons, grand seigneurs, gentlemen, and titled ecclesiastics, also some of the legal profession, and others, who were drawn together by a common love of scientific research." The favorable opinion of these judges has been confirmed by Haller, Cuvier and others, while many of his theories have withstood the light of scientific investigation although founded on no better basis than observation.

Continuing his heretic activities, Palissy was again arrested in 1587, thrown into the Bastile and condemned to die. Execution was delayed by the artifice of friends in power, and the king on a personal visit offered him liberty if he would renounce the Protestant faith. This he refused to do, preferring rather to die at the stake. He escaped this torture, however, dying in 1589 before the sentence was carried out.

Various editions of the works of Palissy appeared in France, in 1563, 1580, 1636, 1777, 1844, and a Dutch edition, said to have been published at Amsterdam, made its appearance in 1655. His writings include discourses on farming, chemistry, geology, forestry, experiences in pottery-making, kinds of clay, the trials of the earliest Protestants and other subjects of his investigations and experiences, and his book entitled "A Trustworthy Receipt, by which all the Men of France may learn how to multiply and Augment their Treasures" treats of agriculture, natural history, a "delectable garden," and a "fortified town."

THE LIGHTS AND SHADOWS BACON THREW ON SCIENCE IN THE NOVUM ORGANUM

By Dr. JONATHAN WRIGHT
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IN the year the Pilgrims landed at Plymouth, Bacon published the *Novum Organum*. In every field of human endeavor certain figures stand forth preeminent in the perspective of its history. Certain of them it is thought, owe their preeminence to their environment. Others are credited with making the environment. There is an ebb and flow to beliefs of this kind among men who know history. As the world lurches toward socialism its opinion is that one man stands on another's shoulder and the environment makes them both. As the world politics marches toward conservatism and the rule of one or a few, historians are busy with the pedigrees and loudly proclaim the man is the epoch. He has made the world which follows him. He has had it in him bred from a line of men of talent. There is an ebb and flow to these world currents which drag one another along. The facts remain the same. The opinions, however, are purely subjective and the facts are twisted, at one epoch and the other, to jibe with them. Francis Bacon lacked neither in his heredity for good blood, as the world judges it, in his veins, nor for the aid of his environment, nor for the stimulus of small means. His environment was one in which the kind of talent he possessed and the lack of honesty and lack of personal regard for a man's honor, which is a part of it, helped him to high office in the state, just as such things do men now. His hands were soiled with bribes given and bribes taken, but so were the hands of his comrades.

All this is not essential for a consideration of what he did for science in the history of thought, but still it would be useful to study it more in detail if space allowed. We might find that lack of money stimulated him to exertions which made him great in public affairs, but we lack any perception of why that should have made him great in science and a great figure in the history of thought. Despite the lack of evidence we have every reason to suspect, from what we know of psychology, that the habits of industry and persistence which the lust for place and pelf magnified in his heredity, played their part in that heritage of science he transmitted to posterity. These made a link between his political life and his intellectual, perhaps which, even in such a cursory essay as this, it is not well to lose from sight.

He was a courtier before he was a censor, but it is in a very censorious way he starts his great work, the "Novum Organum"[1] and we need not fail to find the trail of the tricky politician, the last of places where disingenuousness should show its serpent's head. Dogmatism is his first charge, but the further one reads in the introduction there appears no lack of dogmatism in Lord Verulam himself. He is very severe on the Ancients. In their theories they were intolerant and by persisting in their errors

[1] Of the many scores of editions of Bacon's *Novum Organum* those of Dr. Shaw, 1818—London, and of Joseph Devey, 1902—New York, are the sources of the following remarks, with references to Devey's more recent translation.

they won adherents and they enslaved the minds of their fellow men. It was the sophist of old, who drew Plato's fire and it led to the sophists' lasting and largely undeserving damnation. It was they who followed the Nature philosophers in the evolution of Greek science and it was the sophists who were Bacon's especial antipathy. He joined in the hue and cry he found echoing through the ages to his time and beyond. The world has never paid properly the debt we owe to the men who pointed out the fallibility of the senses and the errors in their own reasonings. They were the first analysts of thought who followed the faulty observations of the nature philosophers and their crude theories, but Bacon thinks of the latter as occupying a prudent place between the arrogance of despotism and the despair of skepticism, and prudence was the deity the courtiers of the court he knew, honored most and most pursued. Bacon draws the to him all sufficient moral. These sophists fell into difficulties when they came to doubt their senses. For Bacon it was folly to follow reason into difficulties. You will search his maxims in vain for the exhortation to "hew to the line and let the chips fall where they may." If a man flinches in the face of philosophical difficulties in thought, his thinking may be safely neglected. There is none of this in Plato and none in Aristotle. They were not favorites with Bacon and he detested Protagoras and his philosophizing and was gratified to think the nature philosophers were content to put the senses to the test.

Bacon himself may perhaps be cleared of skepticism, but he can not escape the inferences of readers as to his dogmatism and arrogance. In his prefatory remarks he says his doctrine or rather his method "consists in determining the degrees of certainty while we as it were, restore the senses to their former rank." Physics especially, but many another territory in the domain of science, would have been led far less widely astray today than it is if the senses alone had been depended on, and if man generally for long had neglected "that operation of the mind which follows close upon the senses" the paths of science would have been narrow indeed. We may still be as open as Bacon was to the charge of arrogance, especially when we think we have just made a long step forward, but instead of being in the "despair of skepticism" we are all not only cheerful, but, despite all, fairly hopeful of the continued progress of science from the results thus far attained in an era when skepticism is rampant. We are disinclined, however, to calculate for the future with any degree of certainty because of Bacon's method or any other in science. Skepticism has saved us from many a despair over the wreckage of a hope, much more over that of a "certainty." Two generations ago Claude Bernard,[2] quoting de Maistre, agreed "that they who make the most discoveries in science know Bacon least, while those who read and ponder him, like Bacon himself, have poor success." Today a distinguished countryman of Bernard remarks[3] that most physical laws, as we now use them, do not belong to the intuitive maxims of $2 \times 2 = 4$, nor the sum of the three internal angles of a triangle equals two right angles, but belong in the category of the laws of probability (not of "certainty") and he quotes the English Quaker Jeans with approval for saying that if you put water on the stove it *may* freeze, but the probabilities are it will boil. Unfortunately there are some physical laws not so secure in their probabilities. A much larger margin is left for skepticism even as to the conservation of energy and the indestructibility of matter.

[2] "An Introduction to the Study of Experimental Medicine," translated by Henry Copley Greene. New York, Macmillan, 1927.

[3] Borel, Emile: *Revue Scientifique* No. VIII, 23 Avril, 1927.

Skepticism flourishes, but hope is not dead. Dogmatism is not so rampant as we find it in Bacon's works, 300 years now after they were first published. We have long since abandoned much of his doctrine, just as we have abandoned much of the formal logic of the old *Organum* of Aristotle. We have abandoned, it is true, much of the formalism and pedanticisms of the Ancients, but the old methods the mind employed in arriving at conclusions persist. Perhaps he was right in asserting that the old scholasticism was fatally erroneous in starting from one supposed fact and by syllogisms clinging to it until a logical conclusion was reached, but it is not at all clear that the natural mental process is radically different when it permits the intrusion of new facts in the chain of logic. That all logic, that every syllogism, is to be banished from the method of science is worse than the worst of the ancient Aristotelian procedure, except for the fact that it is impossible for the mind to work at all and automatically casts it loose to find a compromise.

As for the fallibility of the senses, without perhaps going to the extreme of denying it, indeed he acknowledges it (I.LXIX), he restores them to their position of trust, as Epicurus did, by the mere violence of assertion. They are the only guide we have to direct us, it is true, but he fails entirely to combat the arguments, which the ancients used to dethrone them, and his strictures on those who doubted their reliability are entirely disingenuous. Once taking note of his tendency to this, the reader has every reason for skepticism in the face of his expositions of doctrine, just as the student of nature has every reason for a wary attitude in the face of its problems. This need of caution, this uncertainty is inherent in every problem the man of science thinks he has solved. The greatest of them all, boasting he made no hypotheses, Newton's physics have gone into the discard as expositions of reality. They are and perhaps will long remain useful formulas on earth, but the equations of Euclid and Newton's physics no longer have final values. They are true enough thus far for the man in the street, but they remain no longer a model for the "certainties" of science. There is then full justification to be found in the history of science for the skepticism with which Bacon reproached those who had gone before him. Those who came after him, enthusiastic and eulogistic appraisers of his methods, have gone astray in spite of them if not with them. Perhaps we can do no better than this, but we should remember it when we survey Platonic transcendentalism, for verily all knowledge here below appears based on illusions. Bacon has not presented us with an impeccable alternative on declaring that the system of logic prevailing before him "is useless for the discoveries of the sciences" (I.XI) against which exaggerations even the most partial of modern editors protest, and though nominally we have discarded logic, practically we use it daily in unconventional forms. We may err in the use of it, but no more than we daily do in the pursuit of facts by observation and experiment.

It is the marvel which raises numbers to the level with the divine which is expressed in the common phrase that figures do not lie. Deductive reasoning we know from Bacon is always digging pitfalls of error for science, but Claude Bernard assures us that errors of scientific theory most often originate in errors of fact. Mathematical equations, when freed from physical hypotheses, are a sort of reasoning—a reasoning free of error, with which Bacon was unacquainted. Free from error, observation and experiment never are. This part of his message to the world Bacon subjected to no sincere analysis. It is curious to find him so deprecatory of Aristotle's books on animals. One scarcely knows what he means in the assertion (I.LXIII)

that the old Greek had frequent recourse to experiment in them. It is difficult to find an instance of it, unless we associate the concept of experiment with observation, a practise more common in the writings of Bacon's day than in those of our own. Aristotle's observations on animals have hardly been surpassed, relatively, by modern zoologists, but he has not been credited with experimental methods. In one of his books on animals[4] he treats the matter of method thus: "Ought the writer who deals with the works of nature to follow the plan adopted by the mathematicians in their astronomical demonstrations, and after considering the phenomena presented by animals and their several parts, proceed subsequently to treat of the causes and the reasons why? Or ought we to follow some other method? And when these questions are answered there yet remains another. The causes concerned in the generation of the works of nature are, as we see, more than one. There is the final cause and there is the motor cause. Now we must decide which of these two causes comes first, which second. Plainly however that cause is the first, which we call the final one." On this assumption all antiquity proceeded and it was largely Bacon who reversed the order and tried to reach the final cause by beginning with observations of the "motor cause," but neither he nor his successors have ever reached the Final Cause. Aristotle goes on: "For this is the reason and the reason forms the starting point alike in the works of art and in the works of nature. For consider how the physician or how the builder sets about his work. He starts by forming for himself a definite picture." In illustration of how much we have disregarded Bacon and how nearly we have reapproached Aristotle in our ideas of the way thought runs I quote a review in *Nature*[5] by H. E. Armstrong.

[4] De Partibus Animalium 639 b 5. Oxford transl. by Ogle 1911.

[5] September 24, 1927, p. 433.

In biology it is especially true but even in chemistry "to experiment usefully the motive of the experiment must be first visualized and must be logically considered. . . . judicially interpreted with logical precision." After several centuries of Baconian doctrine this has become a commonplace sentiment of men of modern science. That is what the mind does before it *begins* to experiment and investigate. Whether the attention is first directed toward the problem or not, there is no problem for the mind until that picture is formed, however vague its outlines may be. "In the one case," Aristotle says, "it is perceptible to mind, in the other to sense—(a definite picture) of his end, the physician of health, the builder of a house—and this he holds forward as the reason and explanation of each subsequent step." One may well doubt if Bacon had this text before him when he wrote in condemnation of Aristotle and all his works. It may be well conjectured he had before him the twisted and contorted and corrupt readings of a lot of lazy monks and orientals.

Aristotle in showing the way by which the mind or rather its processes can be analyzed and understood never dreamed, we may be sure, his exposition could be used in the annihilation or sterilization of efficient thought, but such was in a large way the result in the Middle Ages. "The scholastics, it is true, abused the deductive syllogism by employing it in its naked, skeleton-like form and confounding it with the whole breadth of logical theory; but their errors are not to be visited on Aristotle who never dreamed of playing with formal syllogisms" in the prosecution of science. It is one of the modern editors of Bacon who thus speaks when in the "Novum Organum" (I.LIV) Bacon charges Aristotle with making his "natural philosophy completely subservient to his logic." Bacon is evidently pretending he has read what he never saw in Aristotle.

There is not even a suggestion in his "History of Animals" and the long quotation I have made above from his "Parts of Animals" lays bare the synthesis of his thought far removed from any formal logic and illustrative of the way the mind of man works when he thinks. Yet Bacon makes the false assertion not once but twice (I.LXIII). Aristotle had different compartments in his mind for different things and Bacon had evidently never read enough of his real works to know it. He depended on the scholastics of the Renaissance and the Pre-Renaissance for his ideas as to Aristotle, made up in their turn from miserably corrupt texts of Arabian provenance. Bacon may indeed have had an idea of the way the human mind works, but his chief preoccupation seems to have been with the way he thought it ought to work. Yet his own inductive method did much, a very great deal indeed, subsequently to guide the natural mind of man into more profitable ways of working, to broaden the bases on which it must work, but without deductions, theories, hypotheses, it will not work at all and this Aristotle well understood. Apparently neither Bacon nor Newton did. They may have thought so, but there was nothing wrong with Aristotle except the Aristotelians who preceded Bacon. Bacon as well as the Baconians were largely in error, not only as to Aristotle, but as to the natural workings of the human mind.

The conjecture is entirely warranted that, preposterous as it may seem, Bacon was jealous of the place Aristotle still held in the world of thought. "Aristotle himself," he remarks parenthetically, "so distinguished a man and supported by the wealth of so great a king, has completed an accurate history of animals, to which others with greater diligence but less noise have made considerable addition." (I.XCVIII) Despite the narrowness of his soul Bacon had a width of intellect and an acuteness of perception which are unmistakable and undeniable. So apt is he to point out the supposed errors of Aristotle he falls at times into errors himself where Aristotle had found the way to truth. There are others, but his disquisition on sound (II.XLVIII) is an instance where Aristotle following the still more ancient opinion of Alcmaeon has found support and Bacon has found contradiction in modern science.

Bacon, as has been said, may indeed be credited with broadening the bases of science and let no one belittle that service—one of the greatest contributions to the efficiency of human endeavor recorded in the history of thought, but he in no way changed the nature of its basis nor the course of its activity. He moved men greatly to enlarge it, so that no longer as in antiquity its axioms were henceforth to be derived from "a scanty handful of observations" (I. XXV), but, though all of them possibly have their origins in the senses, they are as fallible as those unquestionably arrived at chiefly by the help of reason. It may be remarked that it was not alone Aristotle in the absence of instrumentation went astray with the doctrines of Eudoxus and Calippus, but despite the vastly more correct work of Kepler, of which Bacon might have taken advantage, Bacon felt privileged to build grotesquely erroneous astronomical theories of his own. Jaeger thinks Aristotle's troubles with his astronomical theories drove him to despair. Bacon at least had a thicker skin, having been most of his life a politician, but he understood far better than the ancients the vice of dogma in all logic and the utility in the testimony of controls both of reason and observation. In his day much more than in our own, though still in our own, "this evil insinuates itself craftily in philosophy and the sciences and vitiates every conclusion" (I.XLVI). If his followers had heeded this admonition as much as they did his

objurgation to abandon deductive reasoning science to-day would have been vastly better off. For we need to go back over the history of thought scarcely a hundred years when Bacon dominated it all. Men of great influence upon it read Bacon "a page a day and he was their great light in all things."

The utilization of controls, which we owe to Bacon, we may well boast is the frequent resort of the best workers in modern science, but it is frequently neglected, especially in biology where it is most of all necessary—in medical research. A thousand patients every day are credited with being cured by Dr. Blank's remedy, but none may know how many get well without any "cure" at all. Unfortunately it is not in therapy alone, wherein we all expect to be and usually wish to be humbugged, but it is so in very fundamental fields of medical research and it has led to absurd fads and divagations of the mind, manifold exaggerations of the imagination and heedlessness of the oblivion which falls upon the old when a new aberration appears. The human mind is and has ever been more moved by affirmation and blind to negation. In this respect neither the maxims of Bacon, which warn us, nor the admonitions of wiser experimentalists since his time have markedly affected the proneness of man in this particular to err, but Bacon's chief emphasis was laid upon the errors of deduction.

Before and after Bacon Democritus and Dalton arrived at a conception of atomic structure only long enough subsequently to be established experimentally. The theories of both were entirely deductive and from Sir Joseph Thomson's own avowal we are driven to the conclusion that was the initial process in his own mind when he arrived at the belief the atom could be split into electrons. There were many things afloat in the air of our time, which may well have suggested to a mind so alert the existence of still further divisions of matter, just as now we are beginning to hear imaginings of "dust" on the electrons. We have much evidence in history that there was a sentiment arising among learned men in revolt against the scholasticism Bacon so much criticized when the first James, as learned as any of them, but not so progressive as some, sat on England's throne. Indeed the *de Magneto* which Gilbert, who was court physician to both Elizabeth and James, wrote contains repeated assertions of the advantages of the experimental system. He must have lived on well into the life span and in the environment of Bacon. Before Bacon as he was in this, so also he had a far more correct perception of the celestial mechanics of Copernicus. Bacon after depreciating the ancient nature philosophers, both as to method and attainment, may be said to have placed Copernicus and Kepler in the same class with Ptolemy and Xenophanes, as his editor again suggests, though Kepler had swept away their "futile and false theories." So excellent did Bacon, notwithstanding his ignorance of much of the science of the day, judge his method of studying it that he declared he left little to any acuteness of mind and strength of will to perform (I.LXI). He seemed to think he was largely diminishing the demand for wit and intellect.

He disclaimed any intention of boasting, but one hardly knows what else to call it when he says: "Let those who distrust their own powers observe myself (forsooth) one who have among my contemporaries been the most engaged in public business, who am not very strong in health (which causes a great loss of time) and am the first explorer of this course following the guidance of none," (I.CXIII)—except, we might add Gilbert and the other Bacon and Paracelsus and many others—I am unaware of anything so naively complacent recorded elsewhere in the history of intellectual achievement. Ignorance of the history

of science easily makes the wisest of us an ass. At this place he is apparently referring not alone to some specific material contributions of his own to the solid results of science of which he certainly had little enough to boast, but astonishing to say, he seems to entertain the view he was the first to engage in the pursuit of knowledge by experimental methods and observation. His investigations into the nature of heat were a complete failure, though it is still not an entire success as investigated experimentally by modern physicists. He was somewhat more successful in dealing with the ebb and flow of the tides (I.XXXVI) going astray perhaps only because he knew nothing of the law of gravitation, first demonstrated long after him, nothing of much of the astronomy of his time and long before. Likening the force exerted on the water of the sea to the action of the magnet, which in the way of a marvel had been cited by most writers since Homer, he is sometimes said to have antedated Newton in exposing the physics of the phenomenon. Many of his further ventures into the objective activities of science were not attended by the results he promised others from the use of his methods.

But for all this we owe a large debt to him if only for that exaggeration of the benefits of his method. Science usually makes its strides forward in this way, forcing the emotions rather than the intelligence of men into absurdities and veritable distortions of thought, while panting after the faint glimmer of light pointed out usually by more moderate men, but Bacon was not one of these. It was he, however, who accelerated that momentum which was inaugurated long before him toward a better balance, despite his own lack of it, in the methods of the thinking of men, pushing it into channels of more fruitful endeavor. His foresight in many directions was great. He was one of the few who foresaw to some extent the great part the microscope was to play in the science of the future, though he far underrated it (II.XXXIX). He emphasized and insisted on the value of such things, but his methods were in use long before him. Many of the medieval alchemists, long before the revival of what we call real learning in Italy, were constantly working with experimental methods. No one man began it, neither Roger Bacon nor Lord Bacon nor Paracelsus. The "method" had always existed, though many have talked arrant nonsense about it. Hippocrates experimented on the pig. Celsus tells us of the experimentation of Erasistratus. He tells us of the vivisection of men, an experimentation which is now done more humanely. Galen was probably the greatest of all experimenters in medical research.

The astrologers and the magicians were constantly experimenting in nature, though chiefly on the nature of man and man's credulity. Of this kind and of many other kinds akin to it experimentation is always going on. Even Bacon admits these people practised his methods (I.LXXIII), "rather tending to disturb than to assist experiment," he says, though he does not point out where experiment disturbs old fallacies and where it introduces new ones, but thereby "the alchemists have made several discoveries and presented mankind with useful inventions" (I.LXXXV), finally in our time giving us a glimpse of the actual transmutation of the elements. Yielding as he is to those fakirs of science in his day he has here a sterner word for "reasoners." In a covenanter of the next reign to that in which Bacon flourished his type of mentality would have been called bigotry: "When contemplation and doctrinal science began, the discovery of useful work ceased."

WAVE MECHANICS

By Dr. PAUL R. HEYL

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THE twentieth century has been a strenuous time for students of physical science. Its days have been made up of crowded hours. This is perhaps best realized by those of us whose elementary physical concepts were formed before the discovery of the X-rays. Perhaps as good a way as any to visualize the situation in which we find ourselves is to tabulate briefly (and not in chronological order) the various contributions which have been made to physical science by the first quarter of the twentieth century.

1. The Bohr Atom.
2. The Quantum Theory.
3. The Theory of Relativity.
4. The Equivalence of Mass and Energy.

To these must now be added a fifth—Wave Mechanics.

Looking over this imposing array one may perhaps be pardoned for recalling sympathetically the recent utterance of that English clergyman who suggested the advisability of a ten-year vacation in scientific progress to permit of catching up. But this can not be. The halts in the march of progress are but brief; the bugle blows and we must fall in. There are minds which have produced these new concepts and are restlessly pushing on to others; and there are many others who, if they can not lead, seem easily able to follow. The rest of us are confronted with the stern alternatives of keeping up with the procession or falling out.

These different concepts have not all been equally difficult to comprehend and assimilate. The Bohr atom in particular seems to have made its way into general understanding without a struggle. Perhaps this has been because the concept offers us a clear mental picture, analogous to something with which we are thoroughly familiar—the solar system, also because the mathematics of the subject is closely like the well-known celestial mechanics. Be this as it may, the Bohr atom is undoubtedly the most generally understood of all the newer concepts of physics.

The quantum theory has encountered more difficulty. Even to-day it is still at sword's points with the old established undulatory theory of light. Each of these concepts has its own field in which it is able to show a valid reason for existence.[1] As Lodge says, the two concepts are like a shark and a tiger—each supreme in its own element and helpless in that of the other.

The theory of relativity has encountered perhaps more vigorous "sales resistance" than any other of the newer physical theories. This has been principally because its concepts are of such a nature as to appear to many bizarre and fantastic to such a degree as to be repulsive, and discourage further investigation; and also because its mathematics, while not new, is (or was) quite unfamiliar to all but a few. Yet at the present time the theory may fairly be said to have fought its way to at least a tentative acceptance by the great majority of those qualified to express an opinion on the subject. As a result

[1] "Atoms of Energy." THE SCIENTIFIC MONTHLY, November, 1926.

of the recent work of Adams[2] on the shift of the lines in the spectrum of the companion of Sirius, the last doubt as to the verdict of the three experimental tests suggested by Einstein has been dispelled.

The doctrine of the equivalence of mass and energy, often known as the inertia of energy, is perhaps the best accredited of all the newer concepts, for it comes to us with a pedigree strictly classical, which can be traced back to Maxwell and Newton without bar sinister. This has been elsewhere set forth,[3] but we may briefly review the subject because of the similarity of the argument to that which has given rise to the theory of wave mechanics.

In brief, the argument is that we are confronted by a dilemma: either we must accept the new principle of the inertia of energy or we must abandon the older fundamental principles of mechanics. Now the latter are backed up by ample experimental evidence, and in consequence the new principle, though as yet without any direct experimental verification, rides into acceptance upon the credentials of the old.

And now, with hardly time to catch our breath, we face a new claimant for recognition—wave mechanics; a concept abstract in the extreme as compared with the Bohr atom, yet covering much the same ground, and claiming to do it better.

Simple and natural as the Bohr atom may appear, there is a serious indictment to be brought against it: it is not self-consistent. In order to make his atom work Bohr found it necessary to play fast and loose with accepted theory, discarding it where advisable and retaining it where convenient without any excuse other than necessity. For example, a charged particle such as an electron should radiate energy when revolving in a circle. Bohr says it shall not, but in the next breath admits that it shall radiate while changing from one orbit to another. No one is readier to admit this inconsistency than Bohr himself. His justification for it is that it works well, and it certainly does. The success of the Bohr atom in accounting for chemical and physical facts is almost uncanny. Upon the basis of these untenable assumptions Bohr and his fellow workers have erected a statue marvelously true to Nature, yet this statue has feet of clay. We tolerate it for lack of a better, knowing that it is doomed to fall as soon as a more logical and consistent substitute makes its appearance.

For these difficulties, as well as others less serious, the new wave mechanics offers a simple and logical explanation, and in what it has to offer we may perhaps recognize the first strokes of the handwriting on the wall.

This new concept is but little more than three years old. The first suggestion of it is due to Louis de Broglie.[4] It appears as though de Broglie, on looking over the array of new concepts produced by the twentieth century, had become curious to see what would happen if one mixed them, much as the beginner in chemistry ventures with more or less trepidation to mix the contents of several bottles. So de Broglie seems to have asked himself: "What if we applied the theory of relativity to the quantum theory or to the inertia of energy?" He tried the experiment. The smoke arising from the reaction obscured his vision for some time, but when it cleared away he saw that which he, and Schrödinger after him, have elaborated into the theory of wave mechanics.

[2] "The Present Status of the Theory of Relativity." THE SCIENTIFIC MONTHLY, July, 1926. "The Common Sense of the Theory of Relativity." THE SCIENTIFIC MONTHLY, December, 1923.

[3] "The Inertia of Energy." THE SCIENTIFIC MONTHLY, October, 1925.

[4] *Phil. Mag.* 47, 446, 1924. *Ann. de Physique* 3, 22, 1925.

De Broglie, in his second article above referred to, has set forth in detail the mental process which led him to his new hypothesis. The principle of the inertia of energy states that any mass of say m grams is equivalent to mc^2 units of energy, c being the velocity of light. And the quantum theory rests upon two fundamental ideas. Energy it regards as existing in bundles or discrete units, like atoms of matter; and with each such unit there is inseparably associated a frequency of some kind. The simplest way to picture this frequency is of course as a mechanical vibration of something, but the term frequency as here used is much broader in scope. It may refer to any periodic change, mechanical, electrical or transcendental.

The frequency of this periodic change is usually represented by ν and the quantum theory states that the energy of a quantum, or atom of energy, is proportional to its associated frequency, *i.e.*, represented by such an expression as $h\nu$.

Starting then from our particle of mass m, its equivalent energy may be represented either by mc^2 or by $h\nu$. Expressing this fact in the form of an equation:

$$mc^2 = h\nu$$

"Now," says de Broglie, "this equation refers to a particle at rest. What form will it take if the particle is in motion?"

For the appearance presented by a moving particle to a fixed observer we may invoke the theory of relativity. According to this principle, motion slightly increases the mass of a moving body and apparently slows down any frequency connected with it, as far as a fixed observer is concerned. Hence the above equation, true for a particle at rest, becomes untrue for a particle in motion, the left hand term increasing and the right hand term decreasing.

This unexpected result puzzled de Broglie for some time, but he finally saw a way out. There is a certain parallelism between the situation that thus confronted de Broglie and that which led Einstein to the formulation of the principle of the inertia of energy. In both cases a combination of recognized and well-evidenced principles led to a paradox, the resolution of which could be attained by introducing a new concept. There is, however, an important difference between the two cases. In Einstein's case there was but one way out; his move was forced. De Broglie was not so limited; the solution that suggested itself to his mind was not necessarily the only one possible, though nobody as yet has offered an alternative.

De Broglie's hypothesis was that every mass-particle was enveloped and surrounded by a group of waves (never mind of what) traveling with the particle as a sort of body-guard. Though the group keeps pace with the particle the individual waves constituting the group travel more rapidly, the waves dying out a little distance ahead of the particle and new ones coming into existence a little way behind. Just so successive generations of men pass rapidly across the stage of time while human progress moves onward more slowly. This phenomenon of "group and wave speed" is not new to physicists.

De Broglie found that in order to restore the balance in the equation for a moving body it was necessary to assume that while the mass-particle moves more slowly than light the individual waves of the group move more rapidly, the geometric mean of these two speeds being the speed of light.

Strange as this hypothesis may seem, it soon showed itself fruitful. One of the unexplained assumptions in the Bohr atom was that an electron, as it revolved about the central nucleus, might not keep at any distance from the nucleus

that it pleased. Certain orbits were permissible; the zones between were forbidden. Through them an electron might indeed pass, but in bond and without a stop-over. And Bohr specified a whole number relation connecting these different permissible orbits.

De Broglie's hypothesis led to a simple explanation for this. These atomic orbits are of very small dimensions. De Broglie pictured the electron (surrounded by its group of waves) running round and round in its orbit, the group of waves trailing behind and reaching before. With a very small orbit the wave train might join at both ends, completing the circle. Now if this wave-ring joined so as to make a good fit, crest meeting crest or trough meeting trough, everything would work smoothly; but if there was a misfit interference would be set up and no steady state would be possible. And de Broglie found that the condition for a perfect fit was identical with Bohr's whole number condition for permissible orbits.

But further study showed that de Broglie's hypothesis was unable to carry on its early promise, becoming involved in logical difficulties. However, this suggestion, coming under the thoughtful notice of Schrödinger, was the starting point for the much more consistent and fruitful hypothesis known to-day as wave mechanics.

Schrödinger said to himself: "If such a group of waves always keeps pace with the particle, why the particle at all? Let us see what may be expected to happen if we suppose the group of waves itself to be what we call the mass-particle."

As the first thing Schrödinger saw that it would be necessary to establish for this proposed "wave atom" a satisfactory and acceptable pedigree. He took down from the shelves of science, where it had been resting as a classic and gathering dust for years, a principle originally formulated by Hamilton, considered excellent in its day and always highly regarded by a few, though neglected by the many. Of this principle it has been said by Professor Edwin B. Wilson that it is "the most fundamental and important single theorem in mathematical physics." From it it would seem that the whole of ordinary mechanics is derivable, and from it Schrödinger derived an equation representing very much the same thing as de Broglie's group of waves. By reason of this pedigree and the mathematical relationships involved in it he was able to determine just how such a group of waves should behave under different conditions, and among other things he found that the motion of what may be called the "center of gravity" of such a bunch of waves would, according to the laws of wave propagation, follow exactly the same path as would a mass-particle under the laws of ordinary mechanics. Such a wave-group passing near a mass would be deflected just as though the law of gravitation acted upon it. And in following these laws the wave-group turned out to be more consistent than a mass-particle would be; for it is a remarkable fact, of which we have become fully aware only of late years, that the laws of ordinary mechanics are not applicable to mechanical systems of atomic dimensions; yet even in problems of this character the wave-mechanics proves itself useful, and its most interesting application is to the structure of the atom.

It will be remembered that some few years ago a good deal was heard of a rival to the Bohr atom suggested by Lewis and Langmuir, and known as the "chemist's atom," or the "static atom," as opposed to the kinetic atom of Bohr. Instead of electrons revolving in orbits the Lewis-Langmuir atom supposed the electrons to be nearly stationary, distributed in a regular pattern over the surface of an imaginary sphere, much as

Ptolemy supposed the fixed stars to be set in the celestial sphere. These electrons were considered to be in vibratory motion, but never to move far from their mean position. Whether this concept of the atom was intrinsically incapable of explaining things as well as the Bohr atom, or whether it only lacked sufficiently ingenious handling, it is a fact that this static model was never as fruitful as the kinetic atom of Bohr.

The Schrödinger atom also departs largely from the Bohr concept. It likewise contains no revolving electrons. Imagine a sphere of some material which may vary slightly in density. The simplest type of such a fluctuation will be a slight increase or decrease throughout the sphere as a whole. Let us suppose that the change in density is greatest at the center and next to nothing at the surface. This variation in density may be graphically represented as in Fig. 1.

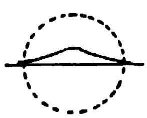

FIG. 1

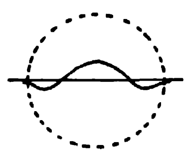

FIG. 2

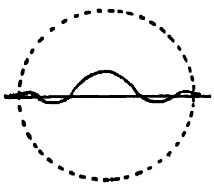

FIG. 3

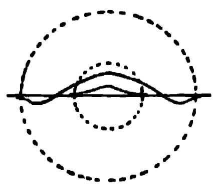

FIG. 4

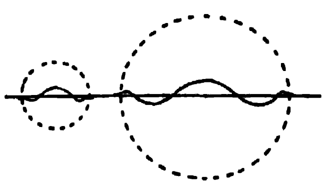

FIG. 5

If the sphere be smaller we may have a similar but more rapid fluctuation in density, just as a short string will give a higher note than a long one.

Again, there is the possibility that the vibration may be broken up into segments, as in Fig. 2 or Fig. 3. And it it possible that several of these modes of vibration may coexist in one sphere. This is essentially the structure of the Schrödinger atom; a sphere fluctuating throughout as a whole, either simply or in a complex manner.

A sphere of what? And what kind of a fluctuation?

Schrödinger postpones the answer to these questions for some time, but finally is forced to reveal the secret because of the impossibility of proceeding farther without it. Prior to this disclosure his differential equations speak only of the fluctuation of a mysterious, ghostly "ψ" throughout a spherical region of space. What is "ψ"?

Schrödinger's answer is a little roundabout and involved. ψ, as he has been using it in his equations is an algebraic complex quantity, involving $\sqrt{-1}$, and like all such complex quantities it has conjugate complex which he denotes as $\bar{\psi}$; and the answer is that

$$\psi\bar{\psi} = \text{electric density.}$$

The Schrödinger atom is therefore electrical in its fundamental nature, like the atoms of Bohr or of Lewis and Langmuir; but there is this distinction: whereas in the Bohr atom the charged electron moves in a circle, and in the Lewis-Langmuir atom vibrates slightly about a mean position, in the Schrödinger atom the electric charge is distributed continuously throughout a sphere, and (as we shall shortly see) is for the most part constant in density, but occasionally subject to slight fluctuations.

The test of the acceptability of any hypothesis is not its conventionality or its grotesqueness, its abstract or simple nature, but what it will do. Nothing in all science has appeared more fantastic

and unreal than the theory of relativity, yet it has made its way into general recognition because it was able to do things a little better than its predecessors.

The same is true of the Schrödinger atom. As we shall see, it is able to do everything which the Bohr atom does, and equally well; and in addition it offers a simple and unforced explanation of "permissible orbits and forbidden zones"; it shows how something in the atom may be in steady vibration without radiating, and how the atom will radiate only when it passes from one frequency of vibration to another. It has a chair empty and waiting for those troublesome things, half quantum numbers, that insist on rising like Banquo's ghost to disturb the feast in honor of the Bohr atom; and (what is regarded as most important of all) it performs easily a task at which Bohr threw up his hands —the calculation of the relative intensities of the lines of the spectrum. Such a newcomer is indeed welcome, though habited in strange dress. Perhaps its apparel is advance information of the coming fashion.

Schrödinger follows up the mathematics of the ψ-vibration and determines the law governing the form of the curves sketched in Figs. 1–3. He finds that any vibration of ψ will extend to infinity in all directions, but that for practical purposes the amplitude of this vibration becomes insensible at a radius of accepted atomic dimensions. Such curves as cross the horizontal axis one or more times (Figs. 2–3) do all their crossing within this radius. In mathematical language, the functions have a finite number of roots, all comprised within the ordinary radius of an atom. And (what is of prime importance) the number of these roots corresponds to what in the Bohr atom is known as the "radial quantum number."

A Bohr orbit may be circular or elliptic. For a circular orbit the radial quantum number is zero; for an elliptic orbit it is a whole number, the ellipticity varying with the size of the number. In the Schrödinger atom a fundamental vibration as in Fig. 1, with no crossing points, corresponds to a circular Bohr orbit, the radius of the Schrödinger sphere corresponding approximately to the radius of the Bohr orbit.[5] A Bohr atom containing two electrons in orbits of different diameters, one circular and one elliptical, would correspond to a Schrödinger sphere such as shown in Fig. 4, where two modes of vibration of different frequencies coexist, the vibration of higher frequency being practically confined to a sphere of smaller radius. The resultant vibration is of a complex form which need not concern us here.

There is in the Bohr atom another characteristic number called the "azimuthal quantum number," and the Schrödinger atom furnishes a corresponding number which does not lend itself readily to depiction or non-mathematical discussion.

The Bohr concept of an electron passing from one orbit to another of different "energy level" has its Schrödinger analogue illustrated in Fig. 5, where a vibration of high frequency, sensibly confined to a sphere of small radius changes to one of lower frequency, requiring a larger sphere to contain it. Both Bohr orbits in this case are elliptical.

Without multiplying illustrations, we may say that for every word in the Bohr dialect there is a corresponding term in that of Schrödinger. And since all the properties of the Bohr atom are expressible in terms of orbits, energy levels, quantum numbers and such like, the Schrödinger atom can perform all the tricks of the Bohr atom, and equally well.

Passing now to the deficiencies of the Bohr atom, let us see how the Schröd-

[5] The Schrödinger sphere having no sharply defined boundary this correspondence can not be other than approximate.

inger atom can contain a steady ψ-vibration without radiating energy. It must be remembered that ψ is not the electric density, but that the latter is dependent on ψ for its value. The mathematics of the subject shows that ψ may execute a simple vibration of any frequency and yet the electric density will remain constant. Classical theory therefore calls for no radiation.

But if the ψ-vibration consist of two simple components of different frequencies, the case is different. There will then of course be a beat frequency corresponding to the difference of the two component frequencies, and the equations show that there will be in this case a fluctuation of the electric density of this difference-frequency—and of course a corresponding radiation. This would give a spectrum of one line. And with more than two simple frequencies present, the number of lines in the spectrum will rapidly increase.

A simple ψ-vibration therefore corresponds to a dark atom. If this vibration changes into another simple vibration of different frequency the final result will be another dark atom; but during the change a single line will be emitted, for we must suppose this transition from one frequency to another to be gradual, not abrupt. The new vibration will doubtless begin of small amplitude, and gradually grow at the expense of the energy of the old vibration until the latter has disappeared. And during this transition there will be a beat-frequency and a radiation of energy.

The ease with which the Schrödinger atom lines up this trick with classical requirements is one of the prettiest things in all mathematical physics.

The Schrödinger atom does equally well with permissible orbits and forbidden zones. The mathematics of the ψ-vibration shows that the diameter of the containing sphere, while not sharply defined, is quite approximately so, and the different diameters indicated for the different frequencies follow a formula which roughly corresponds to the Bohr conditions for permissible orbits.

The half-quantum numbers and the intensity of the spectral lines in Schrödinger's interpretation are of rather too complicated a nature to permit of non-mathematical exposition.

For such happenings as "collisions of electrons with atoms" and "emission of electrons" Schrödinger's concept furnishes a ready mental picture. An emitted electron, according to Schrödinger, would be a little bunch of vibrations thrown off from a larger vibrating sphere, possibly to meet another such vibrating sphere and coalesce with it, either adding its energy to existing vibrations or contributing a new frequency to the atomic vibration.

The Schrödinger atom, because it will do more than the Bohr atom, is an improvement upon it and must supersede it; yet we must recognize that it has its shortcomings, and must sooner or later be superseded in its turn by some concept still more perfect.

One of these shortcomings is fundamental in the theory of wave groups. The existence of such a group, limited in extent, is possible only because it is composed of wave trains of slightly different frequency and velocity. These waves at certain points reinforce each other, giving the group, and at other points destroy each other, limiting the group. But no such group can exist alone. It must be one of a procession of groups all alike, and all traveling along with equal speeds, separated by regular intervals of space.

But it would be ungracious to dwell too much upon the weak points of a new theory which has already shown such real strength. Our part is rather to endeavor to assimilate that which is suggestive and fertile in the new concept (no easy task in a subject of such mathematical complexity), and having done this we may perhaps see clearly to cast out the motes that remain.

CAN BIRDS HOLD INJURIOUS INSECTS IN CHECK?

By Professor E. H. STRICKLAND
UNIVERSITY OF ALBERTA

In this commercial age it would appear that the nature lover has failed to rise above the general trend of thought which views everything around us in the light of its possible financial value.

In days gone by we were accustomed to have a real affection for the many birds that greeted us each morning with their cheery song, or gladdened our eyes with their graceful flight, and were content to accept the pleasure that we derived from them without further question. Now, however, we are only too often asked to regard birds primarily in the light of whether they are liable to affect our bank balance and to guide our actions towards them accordingly.

This alone can be the excuse for the endless stream of articles and pamphlets from the pens of bird lovers who are all bent upon attempting to prove to their less esthetically-minded brethren that birds are money makers and that for this reason, above all others, they deserve our protection.

Unfortunately, in their enthusiasm to reduce our feathered friends to mere articles of commerce it would seem to me that many of these writers somewhat defeat their own object. They so smother the poor bird under the dollars and cents that he is supposedly producing that he is in danger of losing his time-honored status as a most welcome friend of man for his own intrinsic worth.

Extravagant claims are made regarding the financial debt that we owe to birds in their rôle of saving our crops from complete destruction by insects. Few of these claims can be supported by facts. A somewhat typical example of such claims appeared in a recent "official" publication. The writer contended that, in a somewhat limited area, birds destroy a daily average of 21,000 bushels of insects and, thereby, save this area from being transformed into a veritable desert. We have no desire to challenge the accuracy of this computation, but we do claim that the deductions that were made with regard to the significance of these figures are quite misleading in their application to the agricultural prosperity of the excellent farming district to which this reference was made. Were there no birds in that part of the country I venture to state that the agriculturist would not find that he labored in vain to produce a fitting recompense for his toil. It is possible, but by no means certain, that, in the case of a few of his insect foes, he might notice a slight increase in numbers. I am of the opinion, however, that his bank balance would not be sufficiently affected to make a "back to the land" policy the main topic of discussion in the local Legislative Assembly.

If an appeal to the pocket-book is a necessary plank in the platform for giving our feathered friends the protection that is due to them, by all means let us use it to the full, but among ourselves may we not enquire a little more deeply into its true significance? Should we convince ourselves that their financial

value is but a fraction of what has been claimed for them, we need be in no danger of lessening our interest in their protection but should rather raise it to a higher level which is based upon humanitarian and esthetic considerations.

In what I am about to say I lay no claim to being an ornithologist. As an entomologist, however, my duty leads me to study the causes which lead to the rise and fall in population among insect associations. This frequently brings me to the borderline of ornithology.

It would be wise if, at this point, we consider briefly the general factors which govern the abundance of insect populations.

As is well known, all forms of life have the potentiality for a very rapid and steady increase in numbers. This is well exemplified in the case of plant-feeding insects. The average number of eggs that are laid by the females of many moths or beetles, for instance, is in the neighborhood of three hundred. The majority have but one generation a year. A little calculation will give the potential progeny of such an insect at the end of, let us say, three years provided there is no mortality among her descendants.

Year		Eggs
First	1 pair (male & female)	300
Second	150 pairs. X 300 eggs	45,000
Third	22,500 pairs. X 300 eggs	6,750,000

Similar figures to these, some indeed smaller but others very much larger, can be applied to all of the thousands of different plant-feeding insects that inhabit our farms and gardens.

We all know, however, that, with comparatively few exceptions, each of our numerous different kinds of insects is present in approximately the same numbers from year to year. This can mean nothing but that, however many eggs the female of any species may produce, under normal conditions two only of her numerous progeny will reach maturity. In the examples cited 298 out of the 300 perish without reproducing their kind. This mortality, you will see, reaches the surprising total of 99.3 per cent. Should it drop, in the case of any such species to, let us say, only 95 per cent. for a few years, a severe outbreak of that insect is inevitable. On the other hand, if it were to rise, throughout the area occupied by that species, to 100 per cent., which is only .7 per cent. above the normal, the species would be exterminated for all time to come.

Very rarely do either of these contingencies arise. In recent years in Alberta, for example, among all our numerous plant-feeding insects, we have experienced wide-spread outbreaks of two species only. I refer to the grasshopper and the tent caterpillar. Were either of them due to the failure of the erstwhile active birds in destroying a due percentage of these insects? Was equilibrium finally restored by a subsequent superactivity on their part? The answer to both questions is decidedly in the negative.

Many factors, including birds, insect parasites, the direct effect of climate and local shortage of food, all take their toll of insect life. Among these the birds undoubtedly contribute a not inconsiderable share, under normal conditions, in producing the 99.3 per cent. mortality that is essential for the maintenance of an annual equilibrium in the population of these plant-feeding insects. In the case of a number of insects this has been shown to be about 10 per cent. Possibly this figure is somewhat below the average, but we shall see that it makes very little difference, in the long run, whether it be 5 per cent. or 50 per cent.

You will, I think, agree that the ex-

tremely delicate annual adjustment in the population of different species of insects must be controlled by some factor which is far more sensitive to the slight annual fluctuations in abundance, which inevitably occur among these plant-feeding insects, than can be the somewhat hit-and-miss attacks that are made upon them by birds.

We will, therefore, discuss this factor which is paramount in regulating the annual abundance of insects, and will then try to ascertain to what extent its operation is affected by the activity of birds.

As probably all of you are aware, for every plant-feeding insect there are from two to a dozen or more parasitic insects that live entirely at its expense. The simplest relationship between a plant-feeding insect, or "host" as it is termed, and its parasites can best be exemplified by the description of a specific instance. The common cutworm is known to support at least twelve different species of parasites, all of which are either flies or wasp-like ichneumonids. Since the ichneumonid form of attack is by far the more simple and direct we will consider the relationship between the cutworm and but one of its ichneumonid parasites and, for the time being, will disregard all of its associates.

Both the moth into which the cutworm matures and the adult ichneumonid are capable of laying about 300 eggs. Each species is, therefore, endowed with similar powers of extremely rapid increase in numbers.

The moth lays her 300 eggs in the fall. All being well, each of them will hatch into a cutworm in the following spring. At this season of the year, however, there have emerged, from overwintering cocoons, numerous adult ichneumonids. The females of these are armed each with a hypodermic needle-like ovipositor with the aid of which they are capable of planting their eggs deeply in the bodies of any cutworms that they may encounter.

Much as the cutworms prefer to remain below ground, where they are immune from the attacks of the ichneumonids, they are forced to come to the surface from time to time in order to move the more freely in search of food. These occasions provide the parasite with her opportunity for attack. She settles on the ground near the unsuspecting cutworm and runs rapidly forward until she is within striking distance of it. Then, bending forward her abdomen till it projects between her front legs, she poises for an instant, with wings and antennae vibrating rapidly, as though she is carefully selecting the exact spot in which to commit her offspring to its life of imprisonment in the body of the cutworm. The spot selected, she lunges forward and places her egg deeply among the tissues which will provide the resulting grub with its future nourishment. Immediately the head of the cutworm whips around to the attacked spot. Its wide-open jaws, however, snap on empty air for, quick as the counter-attack has been, the parasite is quicker, and is already on the wing in search of a further victim.

For several weeks the attacked cutworm, in so far as its external appearances are concerned, remains perfectly healthy and is normal in its behavior. Within its body, however, is a rapidly growing grub, which most carefully selects a diet of tissues that are non-vital to the existence of its host. At last this grub is mature and is almost ready to turn into the pupal stage in which it will pass the winter. Before so doing it has three important duties to perform. First of all it takes the largest meal of its life. No longer need it spare the life of its host which has yielded, up till the present time, its daily ration of fresh meat. Such delicacies as the heart and the nervous system, which have in the past been

most scrupulously avoided, are consumed in this final gorge.

This accomplished, the grub now gnaws its way through the body-wall of its fast-dying host and, as a final preparation for its long winter rest, it spins around itself a delicate cocoon of silk. Early in the spring it matures into an adult, winged, ichneumonid and this story is repeated at the expense of the next year's cutworms.

From this brief account it is at once clear that every time the parasite is successful in laying an egg in a cutworm, provided no other factor would have destroyed either of them, there will be one less moth in the fall and one additional parasitic ichneumonid in the spring. It is this fact that determines the annual abundance of both host and parasite. Their relative abundance is, however, subject to slight, or at times to very great, variations as a result of the other factors that we mentioned earlier, particularly that of the direct effect of climate. A heavy storm, or a prolonged drought, may be detrimental to the population of either the host or the parasite. On the other hand, unusual climatic conditions may be very favorable to the one without appreciably affecting the welfare of the other.

Let us suppose that, for some such reason, parasites are unusually abundant in a given year. They will then parasitize a larger number of the cutworms than is usual. Fewer moths will emerge in the fall, fewer eggs will be laid and there will, therefore, be fewer cutworms in the following spring. The somewhat superabundant ichneumonids of this generation will, in consequence, have greatly reduced opportunities for egg-laying and their families will be below normal. Their numbers, as well as those of the cutworms, are thus automatically reduced. As we shall see later, this condition is favorable to an increase in the population of the cutworms, and they will continue to increase during the next few years until, finally, both their population and that of the parasite is brought back to its normal abundance.

If, on the other hand, owing to climatic disturbances, the numbers of the parasites are reduced in any year this will lead to reduced parasitism of the cutworms. More moths will emerge in the fall, more eggs will be laid and, in the following spring, cutworms will be unusually numerous, while the parasitic population will be below par. Such ichneumonids as there are will, however, be able to find many more cutworms than is usual in which to lay their eggs and each will, in consequence, raise an exceptionally large family. It is more than likely that the percentage of cutworms that are attacked will be below normal, but the actual number of eggs that will be laid, even in this year, may be in excess of normal, provided the ichneumonid population was not too seriously depleted. By the third spring, then, their numbers may already be considerably above normal. Even when the numbers of the parasites have been so seriously depleted that they are unable to overtake their rapidly increasing host in one year it can but be a matter of a few years before they become so abundant, in consequence of the unusual opportunities that are thus offered for reproduction, that any further increase is prevented only by the fact that the host, however numerous it may have become in the meantime, becomes so heavily parasitized that it is well-nigh exterminated. The superabundant parasites of the next generation then find so few opportunities to reproduce their kind that their numbers, as well as those of the host, are reduced to far below normal. The host, as a rule, is very near to extinction in this year but the progeny of those that manage to survive are subjected to an abnormally light parasitism by the greatly depleted parasite population of this generation.

Their numbers, therefore, begin to increase once more, and during the next few years there will be slight fluctuations in the relative numbers of the host and the parasite till both reach their normal abundance, when a stable equilibrium will be once more established.

A feature of this relationship that may not appear to be quite clear is that of the increased percentage of parasitism which occurs when both host and parasite are present in abnormally large numbers and its reduction when, conversely, their numbers are both below normal. The following illustration may throw some light on this point.

Let us suppose that, in a given area (a quarter-section or a garden, whichever you prefer) there are, in a normal state of equilibrium, ten cutworms and one parasite, and that in these numbers the parasite is just able to keep both its own population and that of the cutworm stable from year to year. Now, for some such reason as we have given above, the cutworm population has increased to 100 and, in consequence, the parasite population has already increased to 10. The ratio of 100 : 10 is obviously the same as 10 : 1, and at first glance one might conclude that these insects were again in a state of equilibrium, even though the farmer now had to contend with 100 cutworms where formerly he had but 10.

We must, therefore, look into this matter a little more closely. In years of normal abundance, in our postulated area, each of the cutworms which inhabited it had but one parasite awaiting an opportunity to lay an egg in it. Now, however, each of them has ten of these enemies seeking its destruction. Its chances of successfully avoiding the attention of a parasite are, therefore, greatly reduced. Conversely, the parasite normally had but ten chances of raising a family whereas now, despite the competition of rivals, it has one hundred opportunities at the beginning of the season. We have already seen that any increase in the numbers of the host insect inevitably leads to a corresponding increase in the numbers of its parasites and we now see that this mutual increase must, as inevitably, be to the detriment of the host in the long run. For precisely the same reasons a reduction in the numbers of the host and of the parasites will be advantageous to the increase of the host until such time as both have regained their normal abundance.

We may sum this up by stating that the average annual abundance of any plant-feeding species of insect is dependent mainly upon the ease with which it can be attacked by its parasites. The population of those which are not well adapted to escape attack will, other things being equal, be smaller than that of those which are the better able, whether by habits or structure, to avoid their unwelcome attentions. The relative number of eggs that are laid by different species of insects has surprisingly little effect upon their annual abundance.

In order that we may return, without further delay, to our original topic of the effect of birds on insect populations I must ask you to accept the statement that, provided man does not upset the relationships between any plant-feeding insect and its parasites, the average population of that plant-feeding insect can never vary very extensively over periods of more than a few years. When they are present in their *average* numbers the majority of our plant-feeders are not sufficiently numerous to cause very severe losses. Unfortunately for us, the factors that maintain the balance among many of these are so delicately adjusted that it requires only a very slight climatic disturbance to inaugurate an oscillation from the mean of relative abundance. For several years thereafter the population of the insect in question is not in a state of equilibrium with its parasites. It rises and falls, now above

normal, now below it till, like a swinging pendulum, it comes finally to rest. In the meantime, however, we may have experienced one or more "outbreaks" of the insect that have caused severe losses to those who are most directly concerned with its activities.

This brings us to the point where we can consider the part played by birds in regulating the average population of these insects. Let us suppose that, in the district to which we have already alluded, the 21,000 bushels of insects that are destroyed daily by birds consist entirely of plant-feeders and that, by the end of the season, 50 per cent. of the original cutworm population has found its way into the crops of these birds. Then let us suppose that, by some fell disease or by the hand of man, every bird in the district is killed in a single year. We will grant, for the moment, that there would be twice as many egg-laying moths in the fall, and therefore twice as many cutworms in the following spring. This will be a bad year for the farmers, but it will be a most favorable one for the parasites. With twice the normal opportunities for egg-laying each should produce almost twice as many offspring as was possible in the case of their parents. Their numbers will, therefore, increase accordingly and they will continue to do so in subsequent years till they have once more reduced their host to the normally small numbers that prevailed when birds deprived them of half of their opportunities to raise a family.

All that the sudden cessation of bird activity would do would be to inaugurate an oscillation in the relative abundance of the host and the parasite, such as might be produced in any season by a slight variation in climatic conditions.

The relationship is, indeed, somewhat more complex than it may appear to be at first glance. For the sake of clarity we illustrated the laws of equilibrium between host and parasite on the assumption that only one species of parasite attacked the cutworm. There may, however, be a dozen or more different species of parasites concerned though their interrelationships do not greatly affect the problem in so far as we have, as yet, presented it. Of more importance is the time of the year at which these parasites and the birds, respectively, destroy the insects from which they are all deriving their sustenance. Despite the complexity of the problem it is, however, obvious that when, after the postulated removal of birds from the complex, an equilibrium between the host and its parasites has been reestablished, the former can not be present in appreciably greater numbers than it was originally. If it were so, as we have shown earlier, the parasites would be able to increase steadily from year to year, owing to the unusual opportunities thus afforded for egg-laying. This would inevitably lead to a more excessive parasitism and a corresponding reduction in the numbers of the host. We can not but conclude, therefore, that the annual destruction of plant-feeding insects by birds has no appreciable effect upon their ultimate abundance.

In this brief statement we have made no mention of the direct effect of the birds on the parasites themselves. In normal years it is probable that, by the time the birds capture and destroy the majority of their complement of cutworms, well over half of them are already parasitized. Not one of these would have produced an egg-laying moth, but from it would ultimately have been bred a parasite. Furthermore, a large percentage of the adult parasites have their invaluable activities rudely terminated when they are snapped up, in the early spring, by a hungry bird.

When one takes all these factors into account I think that you will pardon me for disagreeing with those writers who claim that birds play an important part

in holding down the numbers of the majority of our insect pests. I can not but believe, in fact, that in many instances they are more inclined to have somewhat the reverse effect upon their total numbers.

Some doubt regarding the value of birds to the agriculturist has been expressed by various writers, but it has been based almost entirely upon the question of the direct destruction of parasites by birds. It is mainly among Italian writers that this doubt has found expression and it is of some little interest in this connection to note that insectivorous birds are relatively scarce in the Italian fauna.

Rondini, for example, came to the conclusion, some fifty years ago, that "the policing of the fields can not be entrusted to birds because they are unreliable and kill the guilty with the innocent." Opponents to this view have not been backward in bringing forward arguments to counteract his conclusions. They show that many of the parasitic insects that are found in the stomachs of birds may be parasites of parasites (*i.e.*, hyperparasites) of injurious insects and are therefore themselves injurious, or they may be parasites of beneficial insects that destroy weeds, etc. These arguments appear to me to be a little forced. Even if we agree, however, that the direct destruction of parasitic insects by birds has an inconsiderable effect upon the population of noxious insects, this does not place them upon a firm foundation as guardians of the farmers' pocket-book from steady depletion through the agency of an ever-increasing horde of hungry insects. This is a matter of minor importance compared with the inability of these same birds to reduce the ultimate population of harmful insects by feeding directly upon them.

There is, however, another side to this story which is very much in favor of the birds in their rôle of reducing losses by insects. Even though the parasites, if left to their own devices, will hold plant-feeding insects to approximately the same numbers from year to year as they do with the assistance of birds, the majority of them have a far less satisfactory way of so doing from our point of view.

Though of some hundred cutworms they manage to lay eggs in ninety individuals and thus assure the ultimate destruction of all but ten, every one of these hundred cutworms will continue to feed till the end of the season. Supposing, however, that birds were present in sufficient numbers to have destroyed fifty of these cutworms. Many species of birds, even though later in the summer they may turn their attention largely to a vegetable diet, feed their nestlings during the spring almost entirely on insect food. It is at *this* season that the farmer most desires a friend who will reduce his insect pests. Here the bird scores heavily over his rival parasites. Every time he places a cutworm on his bill of fare that cutworm ceases forthwith to take his daily ration of the farmer's crops. Even though he may somewhat hamper the parasites in their invaluable rôle of keeping the plant-feeders to a constant numerical inferiority, he has the happy knack of killing his victims in the early stages of their meal instead of at the end of it. This is no small item to be placed to the credit of the birds.

On somewhat rare occasions, also, birds may perform a valuable service in nipping an incipient insect outbreak in the bud. The majority of plant-feeding insects, as we have stated, are attacked by a variety of parasites, each of which has a different life-cycle from its associates. Adverse climatic conditions may severely reduce the numbers of one or more of them though it does not often happen that all will be similarly affected. At such times the more fortunate species are not slow to take advantage of the situation and they

enjoy a temporary increase in numbers, to the corresponding detriment of their host. They will continue so to do till their erstwhile rivals have recovered from their temporary eclipse and are in a position once more to oust them from their position of vantage.

Occasionally, in localized areas, conditions may have been such that all the parasite complex is below par in point of numbers and the host increases accordingly. This unwonted abundance of food in a limited area frequently leads to the foregathering of an unusual number of birds, which rapidly reduce the ravaging insect hordes to negligible numbers. Such conditions are not uncommon in orchards. Many of the insects that infest fruit trees are too numerous, even when present in their normal numbers, for the prosperity of the grower. He seeks, therefore, at a considerable expense to himself, to keep them to a constant numerical inferiority by the annual application of poisons, etc. By so doing, he inavoidably reduces the parasite population to an extent that renders them incapable of restoring equilibrium in any year in which his spraying operations have not yielded the full measure of success. Under such conditions it is not surprising that, through some mismanagement, individual orchardists are visited occasionally with serious local outbreaks of some pest that his neighbors have forestalled. As a result of this, however, his orchard may become the recognized "dining-hall" for numerous birds, which remain in it till they have exhausted this local abundance of food and, incidentally, have performed a valuable service for its owner. A similar example is that of the widely advertised feast of the Franklin gull upon the localized outbreak of the Mormon cricket during the early days of agriculture in the state of Utah.

We must, however, be on our guard against accepting the sweeping generalizations which some writers deduce from these somewhat unusual instances.

Consider for a moment a wide-spread outbreak, such as that of grasshoppers over thousands of square miles of prairie. Normally, shall we say, the birds destroy some 10 per cent. of the somewhat sparse population of grasshoppers that inhabits this territory. The latter have, for a period of a few years, succeeded in shaking off the attentions of their parasites to a large extent, and their numbers have increased a thousandfold. Greatly as many birds in this area enjoy a diet of grasshoppers they obtain almost as many as they desire in years of normal abundance. Is it reasonable to suppose that they will continue to destroy 10 per cent. of them now that there are a thousand where normally there was but one? The total population of insect-feeding birds does not rapidly increase as the result of an outbreak of any particular insect, as is the case with parasites. The *percentage* of any insect that will be destroyed by birds therefore inevitably drops below normal in times of wide-spread outbreaks, and they fail signally to play an effective part in the all-essential problem of restoring equilibrium.

In the foregoing remarks I have confined my attention to the general relationship between birds and plant-feeding insects in an effort to offset similar generalized statements, such as those to which I have referred. Though I have selected one insect, the cutworm, as an example the principles outlined can be applied with equal force to the vast majority of plant-feeding insects, such as grasshoppers, tent caterpillars, cabbage butterflies, etc. There may, however, be a number of exceptions to these rules. These occur principally among

insects of foreign origin, that have been accidentally imported into this country. Frequently their natural enemies have not been brought over from their native land with them. So delicately adjusted are the relationships between the majority of parasites and their insect hosts that, in many cases, no parasite, that is native to this country, can turn its activities to the exploitation of an invader. It also happens that the parasites of some of these imported insects, even if they are brought to this country, are unable for a variety of reasons to become acclimated to conditions that exist here. The normal regulative factors which hold these insects to innocuous numbers in their native land may therefore cease to operate in the new land of their adoption, with the result that they may soon prove disastrous to the grower on whose produce they subsist. Birds which feed on this type of insect are of considerable value in the services they render in reducing the human effort that is necessary to keep their numbers in check.

It is possible that a few native insects should be included in this category. Wireworms, for example, are rarely, if ever, held in check by parasitic insects. Certain cultural operations may so reduce the effectiveness of the other natural factors that normally destroy their surplus population that their consequent increase in numbers frequently proves very detrimental to agriculturalists. These cultural operations, however, afford increased opportunities to birds to destroy wireworms by bringing them to the surface and this, in all probability, goes a long way towards counteracting their otherwise harmful effects.

Such cases are, however, exceptional and it is improbable that, in the case of the vast majority of plant-feeding insects, birds are a factor of much importance in reducing their population.

GRAZING AND FORESTS

By Dr. CHARLES WENDELL TOWNSEND

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That fire or the cutting tools of man are destructive to forests is evident, but to affirm that the gentle sheep and cow, or even the belligerent goat and rooting pig are the most thorough-going destroyers of forests seems at first sight to be a rash and improbable statement. A little study and reflection will, however, show that this is the case, and some recent travels in Palestine, Syria, Greece and England, where grazing has been practiced for centuries, has brought this subject very strongly to my attention.

Charles Darwin in his "Voyage of the Beagle" shows very clearly that domestic animals introduced in the island of St. Helena have destroyed the forests there. He was struck by the grass pastures, the hedgerows and the plantations of imported trees, in other words by "the English or rather Welsh character of the scenery." Two plains containing no less than two thousand acres "in former times were covered with wood, and were therefore called 'The Great Wood.' So late as the year 1716 there were many trees, but in 1724 the old trees had mostly fallen; and as goats and hogs had been suffered to range about, all the young trees had been killed." He adds: "It is also said that in 1709 there were quantities of dead trees in Sandy Bay; this place is now [1836] so utterly desert, that nothing but so well attested an account could have made me believe that they could ever have grown there. *The fact that the goats and hogs destroyed all the young trees as they sprang up, and that in the course of time the old ones, which were safe from their attacks, perished from age, seems clearly to be made out.*" The italics are mine. It is a simple and clear explanation of the manner of destruction of forests by domestic animals. Darwin also says: "It is very interesting thus to find, that the arrival of animals at St. Helena in 1501, did not change the whole aspect of the island, until a period of two hundred and twenty years had elapsed."

This very slowness of the process serves to mask its destructive character. The life of man is comparatively short and he sees the forest trees unharmed by the animals, so he is loath to believe that they are factors in deforested regions. If he could revisit the forested plains and mountains, where grazing is permitted, two hundred years later, like Darwin he would be surprised to find the whole aspect of the scene changed to grassy pastures. Not only this, but he would find many steep places, now thickly forested, entirely barren, for a forest can maintain a steeper angle for growth than can grass, and, in the absence of trees, the soil washes away leaving only the rocks. Then, too, the forest floor, the accumulation of centuries, of fallen leaves, branches and tree trunks, all mellowed by decay and its organisms into a rich loam, becomes depleted in a pasture and comparatively sterile, for the grass is cropped short by the cattle and does not remain to enrich and build up the soil. It is true there is a certain amount of enrichment

by the droppings of the animals, but the value of this is often lost by desiccation, and, in the east, much is used for fuel.

Not only in St. Helena, but in numerous other countries where herds and flocks are pastured, are these effects evident. In Palestine and Syria and Greece, wherever grazing has been carried on for centuries, the land is generally desolate. It is true that the rainfall in many places is too scanty to support a forest growth, but one may see in other places, as in parts of Palestine, successful attempts at reforestation, fenced off from the destroying sheep, surrounded by stony pastures of thin soil.

In England and Scotland, however, where the rainfall is plentiful and where the land is not above tree level, this subject is abundantly illustrated. Here, as in St. Helena, there are regions called "Forests," and so designated on the maps, where over large areas not a tree is to be seen. Exmoor Forest and Dartmoor Forest are striking examples. Previous to 1337, Dartmoor Forest had been granted to Richard, Earl of Cornwall, by Henry III, while Exmoor is mentioned as a royal forest in a charter of King John. These were extensive forests in those days. Besides sheep and cattle and hogs, which have been pastured there for centuries, wild ponies and red deer were and still are, in places, abundant.

It may be said, by way of parenthesis, that wild deer, living under natural checks of wolf, cougar or savage, probably never increase to such an extent as to endanger the forests, but, when these natural checks have been removed by so-called civilized man, as, for example, in the Kaibab Forest, deer increase so that the eventual destruction of the forest is likely.

Gilbert White, in his "Natural History of Selborne," says of the neighboring royal forest of Wolmer, a tract of land of about seven miles in length by two and a half in width, that it "consists entirely of sand covered with heath and fern; but is somewhat diversified with hills and dales, without having one standing tree in the whole extent." He states he has "seen cottages on the verge of this wild district, whose timbers consisted of a black hard wood, looking like oak, which the owners assured me they procured from the bogs by probing the soil with spits." He unwittingly explains this "forest without a standing tree" by speaking of the great herd of red deer kept there which, even at the beginning of the eighteenth century, amounted to five hundred head. And he says further: "The manor farm of the parish of Greatham has an admitted claim, I see (by an old record taken from the Tower of London), of turning all live stock on the forest, at proper seasons, *bidentibus exceptis*. The reason, I presume, why sheep are excluded is, because, being such close grazers, they would pick out all the finest grasses, and hinder the deer from thriving."

The scenery about the English Lakes is beautiful and romantic. In many places there are fine trees, but the hills and mountains, whose height never reaches above tree level, are for the greater part treeless. Ancient stone walls, stretching even over the tops of the mountains, indicate the use of these lands for pastures. On Mt. Helvellyn I found sheep grazing on the grassy slopes, but that these same slopes could support trees was apparent, for, in a fenced-in portion, a small planted forest was flourishing. Where trees are planted thickly together, they flourish, even in wind-swept regions where individual trees would perish. That all these regions were formerly densely forested, even on many steep slopes now rocky and devoid of soil, is highly

probable, and that the deforestation came about partly by the axe and fire of man, but chiefly by the slow and insidious, century-long process of browsing animals is clear.

Many of these grassy pastures in England are now so far removed from any trees and shrubs whose seeds would replant them that, even if the cattle were taken away, it would be long before trees and shrubs would spring up. Not so in other regions, as here in New England. "One can easily discover by a simple experiment that in as short a time as ten years a sod-covered upland will return to an incipient forested condition, provided three destroyers—fire, the cutting tools of man, and the teeth of browsing cattle are excluded. Wild roses and blackberry brambles spring up in the grass, and bayberries, hardhack and barberries soon follow. The more cover these give for the birds to nest and roost in, the more seeds are dropped there by these natural forest planters, and sumacks, thorns, rum cherries, apples, maples and red cedars soon appear."[1]

In the dark spruce forests of southern Labrador I have seen extensive light green patches of white birch, indicating a spot where fire had swept through the spruce forest and where the ground had been reseeded by wind-blown birch seeds.

For how many thousand years countless buffaloes roamed the Great Plains we do not know, but one can conjecture that in those parts where the rainfall is sufficient, forests would have prevailed but for them.

We must see to it that our existing national forests do not become grassy and barren wastes by the insidious action over a long period of time of the gentle sheep.

[1] Charles Wendell Townsend, "Sand Dunes and Salt Marshes," pp. 226, 227.

AMERICA'S INFLUENCE ON THE DEVELOPMENT OF THE SCIENCES

By Dr. JOSEPH MAYER
TUFTS COLLEGE

WE Americans have been told time and again by visitors from across the Atlantic that although undoubtedly a great business people we are superficial and materialistic, and that our scholarly attainments are as child's prattle compared with the mature achievements of Europeans. We are merely a practical nation, they say, holding the dollar so close to the eye that we seldom see around it. We have our Edisons, our Bells and our Wright brothers, who apply the results of scientific advance to the practical arts, but Galileos and Newtons are not found among us.

Most Americans have taken it for granted that these criticisms are justly made. We have, in fact, seldom examined carefully into them. It is surprising, therefore, to find that far from contributing little to fundamentals in scientific advance, America stands today in the very forefront with three other nations and that compared, for example, with Italy, the home of Galileo, our country in the past century has produced at least ten times as many great scientists.

Even in early colonial times we made our influence on science conspicuously felt. Two hundred years ago, when modern science was very young the world over, there loomed upon the horizon an American lad who was destined to become not only one of the founders of the Republic, but one of the greatest of scientists.

But before taking up in any detail the influence of America upon the development of science, let us for a moment examine the conditions in this and other countries when the United States was in her infancy, two hundred years ago. Europe was then in the midst of the scientific Renaissance; England had passed through her political revolution; most of the other European nations had become established, and for several centuries a deepening literary and scholastic tradition had been taking root on the other side. Facilities for research were already extensive over there. European universities had been functioning for over five hundred years.

Yet with all this tradition and preparation what had Europe accomplished by 1727? How many great men of science had half a millennium produced? The answer is instructive. From Roger Bacon's day in the thirteenth century to Newton's in the early eighteenth (the latter died just 200 years ago), hardly more than twenty illustrious names sum up European achievement in all departments of science, eight Englishmen, four Italians, three Germans, one Hollander, one Pole, one Belgian, one Frenchman and one Dane standing forth conspicuously. And if we limit ourselves to mathematics, theoretical astronomy and mechanics, which in the five hundred years here under consideration were the only departments of science that had been placed upon a secure footing, half that number of great names comprehend the accomplishment. In the physical sciences, an average of two outstanding contributors per century was all Europe had been able to produce up to 1727. As for chemistry, geology, biology and psychology, they were then hardly more than convenient

labels for separate groupings of unsolved problems. In these fields not even a clearing away of grotesque misconceptions had been achieved. For the most part, even the labels were unintelligible at that time.

Europe had passed through more than half a millennium of scholarly tradition and activity. In America but a century had elapsed since the landing of a handful of Pilgrim pioneers in New England. A small oasis of civilization had taken form in the midst of savagery; but the hostile Indian and the untamed wilderness were still enormous hazards and it was all the sturdy colonist could do to keep the wolf and the tomahawk from the door. I do not suppose there is any one, even among America's most bitter critics, who holds it against her that during this early colonial period of hardship and misery no great scientist arose from her scanty population. One would hardly expect that up to the Revolution or even until after the war of 1812, the United States could become secure enough against elemental dangers and established enough in a scholarly tradition to produce even one conspicuous physical scientist in the face of Europe's meager accomplishment in over five hundred years; and yet in the eighteenth century this youngest and poorest equipped of the nations produced two of the world's greatest physicists—Benjamin Franklin and Count Rumford—besides several other physical scientists worthy of mention.

Benjamin Franklin (1706–1790) had established himself as an educator, successful newspaper man and literary writer in Philadelphia, where among other things he founded the *Saturday Evening Post* and the academy which later developed into the University of Pennsylvania, when at the age of forty he became interested in frictional electricity and began the experiments which were to place him among the illustrious men of science. In 1747 he put forth his famous "one-fluid" theory, which was quickly accepted throughout the scientific world and which has been held until very recent times. It is, in fact, at present experiencing a revival. The theory states that all bodies possess electricity but show no signs of it unless by some means they receive a surplusage, when they may be said to be "positively charged," or lose some of their normal portion to other bodies, when they may be said to be "negatively charged." This simple explanation has sufficed even to this day to elucidate all ordinary static electrical phenomena.

Following the enunciation of this theory, Franklin turned his attention to the meaning of lightning. In experimenting with the Leyden jar, which had been invented not long before for the purpose of collecting and intensifying electrification by friction, he had made use of pointed rods for "drawing off and throwing off the electrical fire," as he expressed it, and he had noticed the remarkable resemblance between the Leyden jar discharges thus affected and the phenomenon of lightning. He therefore determined upon his celebrated kite experiment to see if he could draw down the lightning along a silken string attached to the kite. His success in this daring and startling adventure is common knowledge. It gained him universal recognition, won him honorary doctor's degrees from leading English universities (Oxford, Edinborough and St. Andrews), his election as a fellow of the Royal Society, and the award by England of the famous Copley Gold Medal. In that day no higher recognition could have come to any scientist.

Count Rumford (1753–1814), born under the name of Benjamin Thompson in Woburn, Massachusetts, was eminent not only as a man of science, but also as exemplifying in a very practical way the brotherhood of all men. Virtually forced into the ranks of the Royalists

during the Revolutionary period because of the jealousy of fellow officers in the colonial militia, who resented a mere lad being placed in a position of superior command over them, he left for Europe after receiving his scientific training here, and rose rapidly to prominence in the scientific, social, military and political life of three nations. In England, he became under secretary of state, founded the Royal Institution of London and was elevated to the knighthood; in Bavaria, he was created Count Rumford, served as privy councilor, chief of police, and minister of war, and so revolutionized social conditions in the city of Munich that, although a foreigner and a Protestant in a community predominantly Catholic, the poor of the city spontaneously turned out *en masse* to offer up public prayers for his recovery during a serious illness. In France he married the widow of the distinguished French chemist Lavoisier and became a close friend of Napoleon, Lagrange and Cuvier. By this time the Czar of Russia was urging him to make his home in St. Petersburg and President Adams was offering him the positions of superintendent of the American Military Academy and inspector general of the artillery of the United States. Rumford never lost his love for his native land, despite the jealousies that had driven him from her shores. He left his fortune to Harvard, where under privation and difficulty he had received his training in science.

It would seem that such an active career as Count Rumford's would leave little room for scientific pursuits. And yet his whole mature activity represented a colossal experiment in science. Whether in his project, which never materialized, to survey the White Mountains in this country, or in his work in European armies where he experimented upon the action of gunpowder and projectiles and the nature of heat, or in his introduction of improved methods of horse breeding or in his social experiments of one kind and another, every new experience seemed to present to him an additional opportunity for research and experimentation. The whole world was Rumford's laboratory.

His claim to recognition as a distinguished man of science centered about his investigations into the nature of heat and his attack upon the theory of imponderables, which latter comprehended certain figments of the imagination manufactured to explain well-known physical phenomena. There was the so-called "corpuscle," thought to have something to do with the propagation of light; "caloric," which a body was presumed to draw into itself when heated and lose when cooled; "phlogiston," which a substance was supposed to give off when burning; and "effluvia" which was thought to have something to do with the behavior of electricity. Various fantastic suppositions as to the properties of "caloric" and "phlogiston" had been put forth until the whole subject of heat was almost hopelessly entangled. Heat was generally regarded as a tangible substance, and so was fire.

It was towards the close of the eighteenth century that Count Rumford began to suspect that heat has no material existence, and in 1798 while engaged in boring cannon at a military workshop, he decided to put the caloric theory to a test. His convincing experiments we can not go into here. We can only state his conclusion, which was that heat is a form of motion, caused by the friction of one body against another, and that caloric is a meaningless and gratuitous assumption. By this time the chemists had demonstrated that phlogiston is likewise meaningless. Rumford felt persuaded that he would live to see "caloric interred with phlogiston in the same tomb." His conclusive experiments and a strong attack upon the imponderable theory by another noted

scientist at about the same time, should have been sufficient to mark the obsequies of caloric. It was not until the middle of the nineteenth century, however, that the interment which Rumford expected to witness, actually took place.

The accomplishments of these two native-born Americans were of preeminent importance for further advances in physics. In Franklin's day the phenomena of electricity were still very largely misunderstood. Weird beliefs (such as that goat's blood, garlic, melancholy and seduction influenced or were influenced by magnetic attraction!) were held with respect to electrical and magnetic causes and effects, and current electricity was unknown. Franklin's brilliant experiments and clarifying hypotheses laid the foundation for the remarkable developments which began soon afterwards. . . . On the side of a better understanding of various manifestations of energy, nothing could be accomplished so long as the imponderables continued to raise barriers between heat, light, electricity and magnetism. Count Rumford's experimental proof that caloric is a gratuitous assumption and that heat is a mode of motion led the way to the discrediting of other imponderables, to the reduction of all forms of energy to modes of motion in a circumambient medium, and to a focusing of attention upon the nature of the ether and the source of motion in the structure of the atom. Space will not permit our reviewing in this article the work of other prominent American scientists of the colonial period, notably that of John Winthrop, of Harvard, friend of Franklin and teacher of Rumford, and of David Rittenhouse, of Philadelphia, who was a widely-known astronomer of the time: We must pass on to other developments.

It must not be thought that while America was producing at least four brilliant physical scientists in her first century of scholarly activity, European nations were accomplishing nothing in their sixth. In fact during the same seventy-five years (from around 1727 to the end of the century), France produced eight distinguished physical scientists, Great Britain five, Italy and Switzerland two each, and Holland one. In addition, geology and biology saw considerable preliminary advance, although these had not yet become in any true measure sciences. The outstanding accomplishment of Europe in the eighteenth century was the establishment of chemistry at the hands of several noted Englishmen and the great Frenchman Lavoisier, who was beheaded during the French Revolution, because in a democracy, it was maintained, there is no need for learned men. *La République n'a pas besoin des savants!* Such a conception appears grotesque to us, and yet it is surprising how widespread it is among certain classes even to-day. . . .

The nineteenth century saw an unprecedented development in all scientific departments. When it opened, mathematics, astronomy, physics and chemistry were fairly well established. Before it closed, the practical applications of these sciences had literally transformed the material environment of man, and three new sciences—geology, biology and psychology—had reached their majority, though the claim of psychology to be called a science, even today, may still in some respects be legitimately questioned. In visualizing the development of science it should be remembered that from mathematics to psychology a very definite hierarchy is disclosed. The scientific structure may well be likened to a building several stories high, mathematics constituting the foundation, physics the first floor, chemistry the second, modern astronomy the third, and geology, biology and psychology the fourth, fifth and sixth, respectively. It was not until the last century that the lower stories were com-

plete enough for the rest to be put into place.

In all the unprecedented scientific advance of the nineteenth century, the United States has played an important part, not only in practical applications to art and industry in which she may well be considered preeminent, but also in establishing the fundamental principles without which the applications would be impossible. In Josiah Willard Gibbs, of Yale, she produced a man who might rightly be designated the Newton of chemistry, and in other respects she has actually been in the vanguard of the forward movement.

A comparison of the achievements of American scientists in their second century of scholarly activity with Europeans in their seventh, reveals an interesting situation. There is, of course, legitimate room for difference of opinion as to what scientists should be considered great and who are near great at the present time, but a rough measure of nineteenth century accomplishment can be secured on which most authorities will agree. In European scientific achievement, Italy declined, Holland and Switzerland remained about stationary, Scandinavia and Russia advanced, but none of these nations yielded more than six scientists of note in the past century. Great Britain, France and Germany, however, each produced more than thirty men of outstanding excellence, and so did America. The most phenomenal advance here has been in Germany with the United States second, although it must be remembered that both Great Britain and France had a larger representation of scientists at the beginning of the nineteenth century and that their absolute contributions in the succeeding hundred years have been close behind those of Germany. At any rate, these four nations stand in a class by themselves in respect to modern scientific accomplishment.

Let us turn now to a somewhat more detailed examination of America's recent contribution. In the physical sciences we have mentioned Josiah Willard Gibbs (1839–1903) who was conspicuous as a mathematician, physicist and chemist. Gibbs was born at New Haven and was graduated from Yale, subsequently engaging in advanced study in France and Germany, and returning to the United States to occupy the chair of mathematical physics at his alma mater, where he remained for the rest of his life. Two notable books resulted from his endeavors; one entitled "The Equilibrium of Heterogeneous Substances" and the other "An Elementary Treatise on Statistical Mechanics." He contributed also to the subject of vector analysis, and applied the results to crystallography, to the theory of light and to the closer computation of the movements of heavenly bodies.

Gibbs's monumental work on statistical mechanics and chemical equilibrium saw publication between 1875 and 1880. By that time the young science of chemistry had experienced a considerable advance, especially in the isolation of elements, the determination of their atomic weights, the establishment of the meaning of atoms, molecules, valences, radicles and chemical formulae, and in the phenomenal rise of organic chemistry. Two Englishmen, two Germans, an Italian and a Russian played the important parts here—Davy, Dalton, Wöhler, Liebig, Avogadro and Mendeleeff. But the effects of pressure, temperature, light, electricity and motion upon chemical change—effects of much greater import for chemistry than the developments just mentioned—could hardly be ascertained until the physical processes were themselves clearly understood, and organic chemistry, despite its rapid development, deals, in the main, with only four elements out of ninety.

General or inorganic chemistry had

remained undeveloped, both because the organic branch took most of the workers and because the basis for a further advance was not provided until after the middle of the nineteenth century, when the conservation of energy and the electro-magnetic theories were enunciated and established through the efforts of a brilliant group of Englishmen and Germans—Joule, Kelvin, Mayer, Helmholtz, Faraday and Maxwell most prominent among them. Building upon these physical principles, Josiah Willard Gibbs, with his penetrating insight into the mathematics and physics of chemical processes, cleared away the obscurities and perplexities hampering progress in general chemistry, and laid the foundations for further constructive advance. The colossal accomplishments of this Newton of chemistry are only now coming to be fully appreciated, although Gibbs's work was recognized abroad before it was recognized at home. For quite a period his publications were inaccessible here, whereas German and French translations were in extensive use across the Atlantic.

It has just been indicated that a small group of Germans and Englishmen played the dominant rôles in the advances of physics and chemistry in the first half of the nineteenth century. America still played a lesser part here, albeit the impetus in England followed in large measure the work of Rumford, and Joseph Henry (1797–1878), a native of New York, was a worthy American representative of the New World's contribution at the time. Henry was prominent in mathematics and physics. He was an outstanding experimentalist in the field of electricity, inventor of a number of important electrical devices, and the formulator of the principles upon which Morse later perfected the mechanism of telegraphy. The adoption by the International Electrical Convention of the henry, along with the ampere, the volt, the ohm and the farad bears ample witness to the place this nineteenth century American occupies in the world of physics to-day.

In the past seventy-five years American influence in the physical sciences has been increasingly felt. Along with the work of Gibbs in chemistry should be mentioned that of H. A. Rowland (1848–1901), who made notable improvements in spectroscopic method, enabling the chemist through the use of his concave reflecting grating to penetrate more deeply into the structure of the atom, and who contributed extensively to the study of heat, electricity and magnetism. Richards of Harvard, recent Nobel prize winner for his exhaustive researches into atomic weights, symbolizes the character of American contributions in the present day to fundamentals in chemical science.

At the same time that the principles of general chemistry were being enunciated by Gibbs and that investigations into the secrets of atomic structure were being attempted both here and abroad, a determined effort was made to understand the nature of the ether. It was the startling results of the interferometer experiments of two American physicists, Michelson and Morley, which led to an almost complete overturn of established ideas in physics and to the revolutionary hypotheses of Einstein. Equally important have been other American contributions to physical advance in recent years, as, for example, Professor Millikan's measurement of the electron. Second only to the brilliant discoveries by Europeans of X-rays, radio-activity and the electron, and the launching of the theories of Einstein and Planck, stands the work of American physicists at the present time.

In astronomy, the United States today easily outdistances other nations both in respect to the number of her noteworthy contributors, and in the nature of her astronomical equipment. Than Rutherford, Pickering, Abbe, New-

comb and Hill there are no more important recent astronomers anywhere. Rutherford (1816–1892) was the first to construct a photographic refractor and to apply the methods of photography to the determination of stellar positions. Pickering (1846–1919) elaborated upon Rutherford's work and discovered the first spectroscopic system of binary stars. To-day photographic and spectroscopic methods of stellar research are of prime importance everywhere. Abbe (1838–1916) perfected the weather forecasting service for the United States Government, and his methods were later copied all over the world. Through the subsequent work of the Smithsonian Institution, America is now foremost in the field of weather forecasting. The most recent development here is the establishment of an observing station on Mt. Brukkaros in South Africa, which will be linked by radio with two other American stations (one in South America and the other in California) and will provide still more accurate and comprehensive weather statistics. Newcomb (1835–1909) and Hill (1838–1914) were distinguished mathematical astronomers. Both received world-wide recognition. They applied the Newtonian formulae to troublesome problems of celestial mechanics, especially to the movements of the moon and the outer planets. Hill ranks with Laplace in devising helpful equations for the study of three bodies acting simultaneously on one another in space. In the United States to-day there are many able successors to these men. To repeat, the contributions of Americans to astronomy in the first quarter of the twentieth century outrank by far those of any other nation. We have the equipment and the men to maintain this preeminence. The three greatest observatories in the world are situated here—the Yerkes Observatory of the University of Chicago at Williams Bay, Wisconsin, the Carnegie Institution's Observatory on Mt. Wilson, California, and the Lick Observatory on Mount Hamilton, California.

First place must now also be accorded to America in geology, which came to scientific maturity in the past century. The United States shares with England the honor of establishing this science, each nation developing two geologists of highest eminence—Lyell and William Smith on the other side; Dana and Agassiz over here. Agassiz (1807–1873) was not born in this country, but he made it his own, and did the major portion of his work while professor at Harvard. His discovery of the significance of glacial erosion and drift marked a turning point in geological advance. To Dana (1813–1895), a native American, the world owes the modern hypothesis of mountain and valley formation. His text-book, published in 1863, went through a number of editions, and marked another turning point in geological progress. Together with Lyell and Smith, Agassiz and Dana swept aside medieval conceptions in geology—the deluge, catastrophic change, and cold earth theories—and established the principles of uniformitarianism and orderly development which made possible a real science of the earth.

Preceding these eminent men, two other American geologists deserve mention. Silliman (1779–1864) was one of them. He began his work as professor of chemistry, geology and mineralogy at Yale in 1802, in which fields he stands as a pioneer in this country. In 1818 he founded *The American Journal of Science* and was its editor for twenty years. He had a wide appeal as writer and lecturer, and did more than any one else in the United States to bring the then embryo science of geology to the attention of serious students. He was "probably the most influential representative of science in America during the first half of the nineteenth century." Hitchcock of Amherst (1793–1864) was the other pioneer in American geology.

His books written in 1823, 1848, 1851 and 1853 were extensively read.

Following Dana and Agassiz, an increasing number of American geologists have notably influenced geological advance, conspicuous among them being Newberry (1822–1892), Powell (1834–1902), Gilbert (1843–1918), and Dutton (1841–1912) in recent years and Chamberlin, Davis and Daly at the present time. To Dutton the world owes the establishment of the concept of isostasy, which has apparently solved the problem of the cause of continental elevations as contrasted with ocean-floor depressions. Chamberlin has brought forth the planetesimal hypothesis to explain the origin of the earth. Daly is giving weight in this country to the new theory of gradually separating continents recently enunciated by Wegener in Germany; the theory appears to be of considerable importance. An increasing army of American investigators are exploring the earth's surface to excellent effect; and the greatest geological experimental station in the world is the Carnegie Geophysical Laboratory at Washington, where a corps of scientists are constantly at work investigating the deeper problems of the origin of rocks.

America contributed little of outstanding importance to biology during the first six decades of the century. She had neither the laboratory equipment nor the trained specialists in this field, although she did possess lovers of nature like Audubon (1780–1851), who studied the bird and animal life of the American wilderness and preserved it for science in their faithful drawings and descriptions, and like Baird (1823–1887), and later Goode (1851–1896), whose scientific vision and organizing ability did so much to make possible the twentieth century resources of the Smithsonian Institution, the National Museum and the now world-renowned biological laboratory at Woods Hole.

After the publication of the "Origin of Species," America moved rapidly to the fore in biology as elsewhere. Among the half-dozen professional biologists the world over who had the courage, the insight and the strength of conviction to come out flat-footedly for Darwin's hypothesis, was Asa Gray in America (1810–1888). Allying himself with Huxley and Hooker in England and Haeckel and Weismann in Germany, Gray at Harvard cleared the atmosphere of biological misconceptions in the eastern section of the United States and stimulated able students to further investigation. He also became noted for his work in the classification and description of botanical specimens.

At the same time and a little later, the Great Plains of the United States, in Wyoming, Nebraska and neighboring regions, were being explored for fossil remains by three American zoologists and paleontologists who were soon to receive world-wide recognition for their important researches, especially in tracing the ancestry of the horse and the camel, both of which are now confidently held to have originated in this country, the ancestors of the horse some five million years ago. These men were Leidy (1823–1891), Marsh (1831–1899), and Cope (1840–1897). In addition, Marsh discovered some four hundred new specimens of vertebrates, and Cope's work was so extensive and exhaustive that he was ranked first among international paleontologists at the end of the last century. To-day there is no nation which can match the United States in this biological department. Wherever there are extensive expeditions to discover more about life in the past—in the Gobi desert in Asia, in the tombs of the kings of Egypt, or in tracing the ancient civilizations of South America—able Americans are the guiding spirits. Nor need we stop with paleontology and allied subjects. In every biological department America has its outstanding representatives. Than

Morgan, Wilson, Jennings, Wheeler, Osborn and the late Jacques Loeb, there are no more important present-day contributors in their respective biological specialties anywhere. In laboratory and other resources and in preeminent ability, America now stands in the forefront of biological advance.

In the last of the fields of science to reach maturity or near maturity in the past seventy-five years, namely, in that of psychology, the United States has likewise played an important rôle. In fact she produced the world's greatest psychologist, the much-beloved William James (1842–1910). Psychology had been struggling along for centuries encumbered by metaphysical and philosophical prepossessions. Its emancipation began with the discovery of the principles of physiology, with a better understanding of the nervous and glandular systems and the sense organs, and with the rise of the evolutionary hypothesis. Three distinct lines of emancipation can now be traced—that leading in Germany to the establishment of physiological psychology, that leading in France to the rise of hypnotism and psycho-analysis as agencies of diagnosis in the study of mental diseases, and, in England and America, that leading out from the application of the evolutionary conception to a study of animal, savage, child and individual behavior. James brought those streams of activity together in his epoch-making *Principles of Psychology* published in 1890, since which time the center of psychological advance has unquestionably been in the United States.

Nothing has yet been said about sociology, which is to-day endeavoring to organize the various departments of social study (economics, politics, jurisprudence, ethics and the rest) into one consistent whole. Sociology is not yet established as a science. It must await further developments in biology and psychology, especially in the latter. Considerable preliminary work has, however, already been done, the nineteenth century witnessing the appearance of a Frenchman, an Englishman, and an American—the latter, Lester F. Ward, the most important of the triumvirate—who pointed the way for this modern synthesis of the social studies. At the present time a score or more of able Americans are laying the proper foundations for the new science. In this department of inquiry also, no other nation compares with American activity to-day.

A short article covering as broad and unexplored a field as here surveyed must fall considerably short of being completely satisfactory or conclusive. And yet, certain facts regarding America's contributions to the development of science need no elaborate detail to make them clear. Decidedly handicapped because of her late start in building up scholarly traditions and accumulating scientific equipment—she began five hundred years after Europe—the United States has nevertheless developed scientists of the first rank from the Colonial period onward. In the nineteenth century she forged rapidly to the front until she occupied an enviable place close beside Germany, England, and France, each of which, to repeat, produced more than thirty outstanding scientists, over five times as many as any other nation produced in the same period. America's contributions in every scientific field were notable and in some they were preeminent. And as the twentieth century gets under way there is hardly a department in which she is not outdistancing the savants of other countries.

Far from being merely a practical nation, the United States in pure science is only now getting into her proper stride. She has the financial resources, she can readily secure the needed scientific equipment, and she always has had the native ability and intellectual capacity to take the lead in scientific affairs.

The star of her scholarly accomplishment rose comparatively late, but it is quite apparently of first magnitude, and every sign points to its becoming the most brilliant spectacle in the firmament before the second quarter of the new century has passed.

In conclusion, allow me to say that my investigation of the subject-matter of this article has resulted in the conviction that a more exhaustive treatment, under the auspices of some such organization as the History of Science Society in collaboration with the American Association for the Advancement of Science, would be a decidedly worthwhile undertaking, not because of its demonstration of the conspicuous place held by the United States to-day in scientific pursuits as compared with other nations, although this I feel is of undoubted value despite the supposedly odious character of comparisons, but because there is too little understanding among Americans themselves of the significance of scientific research for its own sake.

Men of science everywhere, and this includes the United States, have labored under enormous handicaps. They have too long been regarded as impractical visionaries, whereas as a matter of fact a vast metamorphosis of man's environment has been brought about through their efforts. The industrial revolution, world-wide exploration and colonization, modern machine industry, the myriad creature comforts now brought to the door of the humblest man through the application of the principles of steam, electric, and gasoline power, the rapid rise in the standard of living which has carried with it an enjoyment of the good things of life for every one upon a scale compared with which the splendors of all by-gone ages put together pale into insignificance—all this has come about primarily through advances in pure science. It is quite true that practical America is eternally indebted to the Galileos, the Newtons, the Lavoisiers, the Franklins and the Gibbses in her rapid rise to wealth and power. It is true that she has benefited much by European contributions. But the post-war situation of the world challenges her as never before. She must continue to depend upon pure science for her material welfare. Europe is burdened with debt and frankly admits that she can not be counted upon in scientific research for a long time to come.

Leaders of industry and public affairs in this country must be made to realize their obligations and opportunity. The scholarly ability is unquestionably here. Let those who benefit so enormously through the practical applications of scientific advance in this, the wealthiest nation on earth, see to it that our universities and other centers of research are supplied with adequate funds and equipment. The scientist has been and is doing his full share despite misunderstanding and hardship. The manufacturers and other capitalists of America must properly maintain their goose if they wish to continue to receive an adequate supply of golden eggs. Happily some of them realize that. Whatever can be done to educate the rest will be of enormous benefit to themselves, to humanity, and to further advances in science.

THE BACTERIOLOGICAL WORK OF JOSEPH LISTER

By Professor WILLIAM W. FORD

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WHILE Joseph Lister may be said to have entered surgery through physiology, his knowledge of bacteriology, his active investigations of microorganisms in wounds and his experiments in his private bacteriological laboratory so affected his surgical work as to raise it from the plane of skillful operative technique, equal to that of his contemporaries, to a plane where his observations, deductions and practice revolutionized surgery throughout the world. To comprehend Lister's bacteriological achievements, we must emphasize primarily the influence of his father, Joseph Jackson Lister, a member of the Society of Friends and a successful man of business, who settled about 1827 at West Ham, a suburb of London, and who devoted his abundant leisure for over thirty years to practical work on the construction of the microscope. At that time the best compound microscopes available were quite unsatisfactory, chiefly because the lenses giving higher magnification produced an excessive secondary spectrum, known as a "coma" or "bur" which interfered materially with accurate microscopic vision. In attempts to do away with this secondary spectrum, Lister discovered the law of aplanatic foci and devised a microscope in which the image point of one lens coincided with the focal point of another. For this notable contribution he was made a Fellow of the Royal Society. It is true that in the subsequent development of the microscope the secondary spectrum is gotten rid of by the use of glass with different refractive indices, that is to say the lenses are corrected for chromatic aberration, but nevertheless, Joseph Jackson Lister is credited with laying down the correct principles for the construction of the microscope. As a young boy, Joseph Lister, the second son, and a brother, were highly trained by their father in microscopy and one of Lister's best papers is the one in which he gives the intricate details of his father's researches. Furthermore, when Lister went up to London to study medicine, his father presented him with an excellent microscope with the use of which the young student was thoroughly familiar. Joseph Lister received his academic and medical training in University College, London, where he came especially under the influence of Thomas Graham, professor of chemistry, William Sharpey, professor of physiology and the pioneer experimental physiologist of Great Britain, and John Lindley, the professor of botany. As a youth Lister was a man of powerful physique, an excellent swimmer and a tireless walker. Much of his leisure time while a student was spent in systematic botany, under the tutelage of Professor Lindley, and his collection of Alpine flowers was one of the best in England. For years he followed the work of a talented brother on microscopic fungi, and actually collaborated with him in some investigations although his name does not appear in the title page of the publications. Finally Lister received a thorough training in French

and German sometime during the course of his elementary education so that he read and spoke both languages with considerable facility. Not a bad equipment for a bacteriologist, French and German, chemistry, physiology, systematic botany and microscopy.

After taking his degree in medicine in London and serving as house officer in University College Hospital, Lister, like many other young medical men of England, was drawn to Edinburgh, then possibly the center of medical training in Britain and her colonies. He was provided with a letter of introduction from Professor Sharpey to Dr. James Syme, professor of surgery in the Scotch University and in many ways the leading surgeon of Great Britain. He made a favorable impression on Syme, was appointed his House Surgeon in the Edinburgh Infirmary and soon after married Syme's daughter, Agnes. This latter event is not without significance in Lister's career. Not that the relationship with Syme gave Lister unmerited advancement but that it did give him, while still a very young man, an intimate association with a surgeon of outstanding ability and experience and one, moreover, who was intensely interested in what became Lister's chief interest, namely, the suppurations which followed surgical operations and certain types of injuries. At the time when Lister entered upon his career, corresponding to the decade before the Civil War in this country, from 1850 to 1860, the complications of surgical operations were heartrending. A large percentage of patients upon whom even the simpler operations were performed, died from what, at that time, was called putrefaction of wounds. Healing, when it did occur, was a slow tedious process, accompanied by sloughing and scar formation. Certain types of suppuration were notably common, especially that peculiar condition known as hospital gangrene, which has, incidentally, never been cleared up for us, even by modern methods. All surgeons were deeply concerned about the mortality from operations, and even the boldest shuddered at his results. Like the majority of the surgeons of his day, Lister was worried about the complications of wound healing and talked the matter over frequently with his colleagues. In that era it was generally believed that inflammation was *nervous* in origin and that the putrefaction which took place in the inflamed area was the cause of death. This putrefaction was usually ascribed to the entrance of the gases of the atmosphere, chiefly the oxygen, as a result of which a kind of autolytic break-down of the tissues resulted. With this prevailing theory of the cause of putrefaction in wounds Lister was thoroughly dissatisfied. As a physiologist it did not appeal to him. In a simple fracture, for instance, plenty of oxygen was brought by the blood stream to the contused tissues and yet they did not putrefy. In fractured ribs the lung might be pierced and atmospheric oxygen be present at the site of injury and yet putrefaction did not appear. As a practical surgeon also, the theory did not appeal to Lister. He saw putrefaction develop after slight abrasions of the skin or small punctured openings when the patients were in the hospitals, and large open wounds sometimes heal without suppuration when the patients were in their homes. Over this putrefaction of wounds Lister worried and studied for several years, trying out different types of dressings without success. About 1865, however, a colleague of Lister in the University of Glasgow called his attention to the work of Pasteur on the causes of fermentation and putrefaction which had been published about a year previously. Lister secured the original papers and studied

them thoroughly. Struck by the simplicity of the experimental work, the clarity of description and the soundness of conclusion Lister became an immediate convert to the new doctrine. From this time on we may trace two distinct lines of bacteriological work in Lister's career. He fitted up a private laboratory, perfected himself in the technique of Pasteur and conducted bacteriological investigations over a long period of years. He repeated many of Pasteur's experiments and came to the same conclusions, namely, that fermentation and putrefaction in properly sterilized sugar and protein solutions are always the result of the introduction of bacteria from without, especially from the atmosphere. In the course of this work, Lister employed human urine. After many unsuccessful attempts to obtain and keep it sterile he finally succeeded, by careful attention to the cleaning of his glass ware, and in an introductory lecture delivered in the University of Edinburgh in 1869, he pays high tribute to Pasteur and then describes his own work. At this address he exhibited urine kept free from microorganisms for six months. Similar material he had exposed to the atmosphere and noted in it a rapid decomposition. Some of this decomposed urine had been transferred to sterile urine which in its turn decomposed. Lister did this work in ignorance of similar unpublished work by Pasteur with the same fluid. From this time Lister became the chief advocate of Pasteur's theories, at least as far as the English-speaking world is concerned. As he said, the conclusions of a trained investigator from properly controlled experiments are convincing, while the failure of poorly trained workers to obtain the same results, with improperly controlled technique, may be disregarded.

If Lister had stopped at this point, he would have had an honorable place in the historical development of bacteriology, but little more. His merit lies in his vision. He saw that if Pasteur was right about the causation of fermentation and putrefaction in flasks of nutrient material a similar principle might hold for the putrefaction of the tissues. In just the same way as dust laden with bacteria dropped upon the surface of the fluids, so might bacteria drop on the surface of wounds. Furthermore, if this were the explanation of the putrefaction of wounds, two things were necessary to prevent it. First, the bacteria already in the wound must be killed, and second, a dressing must be applied which was free from organisms and impregnated with substances which would destroy any bacteria which might further be deposited. We have here, it seems to me, one of the most beautiful examples of reasoning by analogy and a striking incident in which a pure hypothesis led to fundamental changes in our entire conceptions. For it must be remembered that at the time Lister studied and confirmed Pasteur's work and applied it to surgery not a particle of convincing evidence had been brought that bacteria are the cause of suppuration and putrefaction in the animal body, and one might even go further and say that no convincing evidence had thus far been presented that bacteria are the cause of disease. For this period in Lister's work may be roughly placed before 1870, six years before Koch proved that the anthrax bacillus is the cause of splenic fever.

Lister immediately began experimental work on the problem outlined. After first trying out other substances, he selected carbolic acid as the most suitable for his purposes. This substance had been discovered by Lemaire, in France, and already had been employed

in a desultory fashion in surgical dressings. Lister's attention to it came from the fact that it was being used extensively in the sewage fields of Carlyle, England, a short distance from Glasgow, where it had been noticed that its use was followed by a diminution of parasitic diseases among the cattle there. Lister also knew that its value in preventing the decomposition of organic materials had been demonstrated by Lemaire. Carbolic acid was available to Lister in the form of German creosote under which name it had been imported into England. After considerable study of its properties Lister decided that it was suitable for his purposes and employed it first in 1865 in the disinfection of the open wounds in compound fractures, then covering these wounds with a dressing made up with carbolic acid as a base. To Lister's immense gratification the compound fractures so treated healed without suppuration. The further development of his practice in the employment of carbolic acid belongs to the story of Lister's surgery. It should be emphasized that Lister used carbolic acid with the distinct idea of destroying the bacteria already present in a wound and of providing a dressing which would kill the organisms further deposited upon it. In other words, Lister was the first person to deliberately attempt the *disinfection* of wounds and herein his work differed radically from that of some of his predecessors, who had employed carbolic acid as a surgical dressing. Any other substance which would destroy the bacteria in wounds might have been acceptable to Lister, but it happened that carbolic acid did the work required of it and at the same time anesthetized the tissues so that its application was painless. Finally, healing of the tissues progressed favorably under the dressings. As time went on, Lister tried out a great many other disinfectants (chloride of zinc, bichloride of mercury, etc.) and later devised a new one, the double cyanide of mercury and zinc, which he believed was not inactivated by the serum and tissues.

A word or two should now be said about a much debated point. Impressed by Pasteur's work on fermentation and putrefaction, Lister regarded the atmosphere as the source of danger to open wounds, believing that bacteria were carried to them with particles of atmospheric dust. It should be noted, however, that from the very first Lister believed that bacteria might gain entrance to wounds from several other sources, chiefly from the skin of the patient, the hand of the operating surgeon, his instruments and the dressing applied. So we find him rapidly developing a technique for the disinfection of the skin, the cleansing of the hands, the sterilization of instruments and the preparation of bacteria-free dressings impregnated with substances capable of destroying micro-organisms. As was to be expected, he placed chief reliance on carbolic acid for this purpose. Later Lister's ideas changed as to the source of the bacteria which brought about putrefaction. He was eventually convinced that the bacteria of the air are harmless, calling definite attention to this at the London Medical Congress in 1881 and confirming it at the Berlin Congress in 1890. He therefore abandoned his complicated apparatus for spraying the atmosphere with carbolic acid. The main thesis that bacteria are the cause of the suppuration and putrefaction of tissues Lister never doubted, despite the opposition of many of his colleagues and despite the fact that as surgical technique improved and surgical bacteriology developed, successful results were obtained by other methods. It must be admitted that carbolic acid, used in such quantities as made necessary by Lister's original methods,

was a dangerous agent and attacks of haemoglobinurea were not uncommon in a surgeon, after a long operation in which his hands were frequently immersed in strong solutions, or after a day spent in the atmosphere of carbolic acid produced by Lister's spray. On one occasion indeed Lister was invited to examine the work of one of his colleagues who had gotten brilliant results without employing carbolic acid. His comment is interesting. He admitted that the results of the other surgeon were as good as his own but he said that while "I do not understand the matter thoroughly, I will never abandon the thesis that bacteria are the cause of putrefaction in wounds and that their entrance must be prevented."

During the course of Lister's observations on the disinfection of wounds and the perfection of his technique he controlled his work constantly with his microscope, studying his tissues and looking for micro-organisms. One might ask at this point why Lister did not attempt to bring satisfactory experimental proof of his thesis by the inoculation of animals with septic material. Koch did. As soon as Koch learned to handle bacteria and was satisfied that he could obtain them in pure culture, he took material from suppurating wounds, inoculated animals and produced infections. Koch's paper on Wundinfectionskrankheiten, published in 1878, brought final proof of the relationship of bacteria to surgical infections and is one of our great classics in bacteriology. The answer to the question I have just raised is found in Lister's own words. As he said, the daily observation, carried out over long years, that micro-organisms are always present in suppurating wounds and are not to be found in wounds healing without suppuration, was far more convincing to him than any amount of experimental work on animals. Lister did, however, carry out several procedures which in the main established his thesis experimentally. Thus he obtained blood from animals under antiseptic precautions and succeeded in keeping it free from putrefaction indefinitely. Portions of this sterile blood he now exposed to the atmosphere, noting the decomposition which followed. Bits of this septic material were now transferred to his sterile blood and characteristic putrefaction promptly ensued. Lister also produced suppuration in animals. In his attempts to devise methods for the suturing of blood vessels, he cut down on the larger arteries, tied off short segments and introduced small glass canulas containing putrefactive products. The subsequent spread of the suppuration Lister noted with care and interest.

So much for the bacteriological aspects of Lister's work on wounds from which we may draw three main conclusions. Lister was the first to establish the thesis that bacteria are the cause of suppuration and putrefaction in the animal body; the first to attempt the disinfection of infected tissues; and the first to devise methods to prevent suppuration and putrefaction by preventing the entrance of micro-organisms.

The rest of Lister's bacteriological work may be dismissed with a few words. It relates chiefly to the bacteriology of milk and he was hampered, like other men of his generation, by his inability to obtain pure cultures. He did prove that milk, as it comes from the animal, is generally free from bacteria and if protected from subsequent contamination remains clean and sweet. He further observed that all samples of milk, whether gotten at the dairy farm or at the city shops, reveal the same types of micro-organisms. In other words, milk exerts a selective action on

bacteria so that only certain kinds survive. The predominant species he obtained repeatedly and probably in pure cultures. This species he named *Bacterium lactis.* He made many attempts to devise methods to isolate single species of bacteria but those proved to be of little value after Koch discovered his poured-plate method and his solid media. Some of his experiments were highly ingenious and his results must have been beautiful to behold for he had a system of what he called "glass gardens" in which he cultivated all sorts of pigmented organisms. Apparently he never tested his disinfectants against bacteria as has been done ever since Koch worked out the procedure for this purpose. To the end of his life, Lister remained an enthusiastic bacteriologist and all of his papers show that he was thoroughly conversant with the development of this branch of science and appreciated its possible benefit to the human race.

Finally a word should be said about Lister's method of publication. Nearly all of his results, both surgical and bacteriological, are given in addresses. Some of them were delivered before scientific societies. Several in which his most important contributions are described were presented to his medical students in Glasgow, Edinburgh and London. One feels that he was an enthusiastic and meticulous teacher and gave his best to the throngs of young men who attended his clinics and followed his ward rounds. He was an advocate of clinical rather than of didactic instruction and always preferred to have his patients before him when he discussed operations or treatments. In reading his papers and studying his life one is convinced that the long opposition to his beliefs and practice shown by some of the surgeons of Great Britain, particularly by men in London, depressed him beyond measure. He evidently believed that lives were being wasted by the inability of his colleagues to see the truth as he saw it and by the refusal of some of them to come to his clinic, see his results and learn his methods. He therefore concluded possibly that it was wiser to scatter the seeds of the new truths in the fertile soil of his students and young internes rather than to cast them on the stony ground of his contemporaries. Whether this be his motive or not, it is significant that many of his followers were recruited from the crowds of young men who flocked to Edinburgh to attend his clinic and from the few who remained in his surgical service.

THE RACE FOR SWEETNESS

By Dr. J. J. WILLAMAN

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ABOUT a year ago a vigorous campaign was launched in one of our corn belt states to introduce glucose as a household sugar. The glucose offered was a beautifully white, crystalline, coarsely powdered material, in appearance much like ordinary granulated sugar except with less luster. It was very pure: except for about eight per cent. of moisture it contained only 0.2 per cent. of impurities, thus comparing very favorably with its old rival, cane sugar. It was perfectly wholesome; it did not even need digesting, as did its rival; it dissolved readily, and was entirely free from any unusual or undesirable flavor. The slogan "eat corn sugar and help the farmer" was invoked, and every means was tried of inducing the people to acquire the glucose habit. The effort, however, was practically a failure. Why? Because glucose isn't sweet enough.

Most people know that the sugars are good food. Some people know how many calories there are in a piece of fudge. A few people know that sugar is not conducive to reducing. But every one knows that he or she *likes* sugar because it is sweet; and there is really no other explanation for the increase in consumption of sugar than that we are continuously craving more and more sweetness. The records show us that our consumption of sucrose (cane or beet sugar), which has been climbing steadily for decades, is still climbing, and that it has reached the really large figure of some 110 pounds *per capita*. Our sweet tooth is our strongest dental characteristic.

Little wonder, then, that glucose was disfavored because of its lower sweetness when it was used in the ordinary household ways. It mattered not that it was a quickly available sugar for the body—actually pre-digested, one might say—that eating corn sugar would help the corn farmer (although of course it would not help the beet farmer); and that it could be bought for about a dollar a hundred less than sucrose. It was conspicuously less sweet than the granulated sugar to which people had become accustomed, and they therefore got away from it just as soon as they could exercise an unhampered choice of sweetness.

THE SWEETNESS OF SUGARS

This engenders the question, how sweet is glucose and sucrose, and the rest of the sugars? Unfortunately we don't have a convenient yardstick for measuring this form of physiological response, as we measure sound by vibrations per second and color by wave-length. The best we can do is to establish a relative scale, and compare one sweet substance with another. Even this is astonishingly difficult, as can be appreciated only by trying it. Until a few years ago we had no significant figures for the relative sweetness of the sugars. Then some rather accurate measurements were made in the Home Economics Department of the University of Minnesota. From the data there developed the sugars can not only be listed in the order of their sweetness, but actual numerical values assigned, giving sucrose arbitrarily a value of 100. The values are given in the following table:

RELATIVE SWEETNESS OF CERTAIN SUGARS

Fructose	173
Invert Sugar	123
Sucrose	100
Glucose	74
Xylose	40
Maltose	32
Rhamnose	32
Galactose	32
Raffinose	23
Lactose	16

Perhaps a word would be in order as to the tasting technique in evaluating these sugars. Mrs. Cecil Stone Wahlin, a graduate student at that time, conducted the work. After trying several tasting procedures with no success, she finally decided upon the following: A series of solutions of a given sugar in distilled water was prepared, ranging in concentration from that which she was sure would be markedly sweet to every one, down to a concentration which would probably not be perceptibly sweet to any one. A subject, usually a woman, was seated, blindfolded, and given a sip of distilled water. Then the tip of her tongue was swabbed with cotton, and a drop of one of the solutions placed on the tongue. Immediately the "patient" would say, "Yes," "No" or "Doubtful," meaning that this solution did or did not taste sweet, or that she could not decide. By skipping around among the solutions, and recording the decisions, a very good idea could be obtained as to the weakest solutions of that sugar that could be tasted. And by using 15 or 20 people on each sugar the accuracy could be greatly increased. From data so obtained, the "threshold value" of each sugar was calculated. This value is the lowest concentration which is detectably sweet to 90 per cent. of the people tasting. The other 10 per cent. is designed to include the erratic, undelicate tasters, those whose judgment was perverted by having candy too near to the time of testing, and those whose nerves were dulled by too little sleep or too much movies. From the threshold values were calculated the relative ratings listed in the above table.

WHY GLUCOSE FAILED

The item in this table to be noted at this moment is the sweetness value for glucose.

This sugar, which, as has been said, was spurned for home use, is only 74 per cent. as sweet as sucrose; and, if we allow for the 8 per cent. of moisture in it, this figure is reduced to 68 per cent. It is quite plain why a cup of granulated glucose did not possess the sweetening power of a cup of the usual granulated sugar.

THE VARIOUS SUGARS

It has been implied above, and no doubt most readers are well aware, that there are several different chemical substances which belong to the class of sugars. Of course legally there is but one "sugar," and that is the product derived from the cane or beet. But since in this article we do not have to be legal, but are privileged to be accurate instead, we shall ignore legal imputations and shall call the sugars by their proper names.

The sugars are those carbohydrates which taste sweet, are soluble in water and form crystals. This will suffice for a practical definition. For comparison, some non-sugar carbohydrates might be mentioned: starch, glycogen (in the liver and muscles), cellulose (as cotton, paper, linen), dextrin (as the mucilage on postage stamps) and gums (as cherry and spruce gum). The commoner sugars can be divided into two groups, the monosaccharides and the disaccharides. The first group includes glucose, fructose and galactose, and the second, sucrose, lactose and maltose. There are, of course, several other sugars known in nature, and many others have been prepared synthetically, but these need not concern us here.

Our thesis is, then, that sweetness is the most important property of a sugar; and that when a new sugar bids for favor in the world's commerce it must either be conspicuously sweet, or it must be compensatingly cheap and abundant.

From time to time it is fitting that we take an inventory of sugars as well as of any other commodity—so as to readjust, if necessary, our viewpoint and attitude. In the case of sugars an inventory would involve a survey of the known and commoner sugars found in nature, and a consideration of them as possible commercial sugars. Such an inventory, together with a brief discussion of the occurrence and characteristics of the sugars, is attempted in the following paragraphs.

Glucose

Glucose is unquestionably the most widely distributed of the sugars. It is the sugar burned in the bodies of higher animals, and hence is the sugar that occurs normally in the blood to the extent of about 0.14 per cent. It is probably the sugar found in normal urine as a trace, and in diabetic urine in conspicuous amounts. It probably is also the sugar burned by the lower animals, and by practically all plants. We could generalize and say that it is the universal fuel sugar. This means that when other sugars are ingested in the food they are ultimately converted into glucose before burning.

Glucose, which is also called dextrose and grape sugar, occurs abundantly in fruits and some vegetables; the brown powder on the surface of some raisins and prunes consists of glucose crystals. When honey crystallizes it is glucose that separates. About a third of molasses and a fourth of sorghum is glucose.

The most important occurrence of glucose is not, however, in the form of the sugar itself, but in its compounds. For example, it combines in nature with fructose to form sucrose. It combines with itself in one way to form maltose and then starch; in another way to form cellulose. Therefore, when we reflect that sucrose is the premier commercial sugar at present, that starch is our most important source of calories, and that cellulose constitutes the structural material for all the higher plants, we can not but be impressed with the tremendous rôle that is played by glucose in our present economy.

Commercial glucose is not obtained as such from a plant or animal material. It is obtained from corn starch in this country and from potato starch in Europe, and until recently almost entirely in the form of the so-called corn sirup. The starch is separated from the hull and the germ of the corn grain in the usual manner for preparing starch, and it is then heated under pressure with a small amount of acid. A series of changes takes place that can be stated,

starch → dextrin → maltose → glucose.

The various stages of the process overlap; hence the course of events can be stopped at such a point as will give the desired proportions of these substances. For corn sirup, it must not be allowed to go completely to glucose, since this sugar crystallizes too readily. A certain amount of dextrin is retained, which prevents this crystallization. Hence the average analysis of corn sirup shows about 25 per cent. of glucose, 12 per cent. of maltose and 37 per cent. of dextrin.

If, however, dry glucose is wanted, the reaction is forced to completion, the glucose solution is decolorized, evaporated to a thick sirup, and allowed to crystallize; and then the crystals are separated, washed, dried and bagged for market. This process has been so perfected during the last few years that the resultant glucose is pure white, as dry as cane sugar, and, as stated before, contains only 0.2 per cent. of impurities other than about 8 per cent. of moisture. It is made to the extent of thousands of tons, and sold for a lower price than is sucrose.

What is the future for this glucose? Probably no one would hazard a prediction. For many manufactured food products, for example, certain candies, cookies, fancy crackers, bakery goods

and ice cream, it has certain advantages over sucrose, because of the physical properties of its magmas, and because for some purposes lower sweetness is required. As a household sugar, and as a general sweetening agent, it carries a handicap in the race.

Glucose from Sawdust

If water be made to combine chemically with cellulose, glucose is formed. Such hydrolysis can be brought about in various ways, and the methods have been studied for many years. But this is one of the main laboratory processes which is difficult to apply commercially. A few years ago the Forest Products Laboratory at Madison, Wis., had considerable success in converting sawdust into cattle feed; but apparently there is not as yet a pinching need for sugar feeds, and the process has not advanced appreciably.

Again, the same laboratory experimented with the fermentation of the glucose formed from sawdust, with the idea of utilizing waste wood materials for power alcohol. About 30 per cent. of the sawdust could be converted to glucose, and this was readily fermentable. But this material has to compete with cheap molasses for alcohol production, and so far it has not made much headway.

At the Congress of Chemists in London last summer much discussion was leveled at three different processes for the hydrolysis of cellulose. Each of these processes claimed a yield of at least 60 per cent. of the weight of the wood as glucose, with the theoretical yield placed at 68 per cent. Such yields would be a decided advantage in the attempt to place ethyl alcohol motor fuels on the market in competition with gasoline and with synthetic methyl alcohol.

Fructose

This is the queen of sugars for sweetness. It leads sucrose in this respect farther than sucrose leads glucose. For many years it has been recognized as the sweetest sugar, without any definite value being known; and it has long been predicted that if it could only be prepared in commercial quantities it would lead the sugar world in popularity. But the great stumbling block was its obstinacy in refusing to crystallize. It could be obtained in sirup form, but as a sirup it could hardly hope to compete with dry sucrose, or with the other sirups having distinctive flavors. Therefore hope for this queen languished, until a few years ago the problem was tackled by some of the chemists in the Bureau of Standards in Washington. Under the proper conditions of persuasion the queen was induced, quite lady-like, to change her mind; and most beautiful white crystals were obtained. The crystals formed copiously, and could readily be separated from the molasses and dried.

The process is still in the experimental stage, but semi-commercial scale operations indicate that there is every chance of its succeeding ultimately. Mr. Hugh Farrell, in his recent enlarged edition of "What Price, Progress," says,

> Right off you will not get the full significance of what this means. In the first place, it means that this country is on the verge of complete independence of foreign sources of sugar supply. (It imports 8,000,000,000 pounds of sugar every year, four fifths of all it uses.) It means that science and research have found the solution of the "farm problem" for which the politicians have been blindly groping, and it also means the gradual development of a vast new industry based on sugar from corn and Jerusalem artichokes. And that may mean that this country is to become a source of supply of the 40,000,000,000 pounds of sugar the world consumes every year.
>
> The only information I have as to the cost of production of levulose (the other and the uncertain factor in the calculation) is a statement made by representatives of the Bureau of Standards to the effect that levulose can "probably be produced on a competitive basis" with the older sugars.
>
> The ramifications of this possible revolution in a great world industry extend in all directions and into all lines of human activity; they touch home investments, international banking, world shipping and agriculture.

Fructose, like glucose, occurs very widely in the plant world, especially in fruits; it constitutes half of honey, and about the same proportion of molasses and of sorghum as does glucose. None of these sources, with the possible exception of molasses, could be used for the commercial production of the sugar. Just as glucose is obtained most easily and cheaply from starch, so is fructose obtained from a starch-like substance called inulin. This is found to the extent of 12 to 15 per cent. in the tubers of the dahlia and of the girasole, or Jerusalem artichoke, and to a lesser extent in the roots of the dandelion and the chicory.

The Bureau of Standards investigations have been largely with the artichoke, and this in many ways seems to be the most promising source. It has some decided agricultural advantages. It is a vigorous plant, and is not especially particular where it grows. It produces large quantities of tubers, from 700 to 1,000 bushels per acre being an expected yield. It has practically no insect enemies or fungus pests. It is entirely a machine-cultivated crop.

And these qualities are resident in the plant as we find it now. What improvements may we expect if it is put through a process of education such as the sugar-beet received at the hands of the plant breeder and the chemist?

Molasses may prove to be another source of fructose. In the manufacture of sucrose from the cane or beet, the removal of one crop of crystals after another results in the gradual accumulation of the non-sucrose constituents, largely fructose and glucose, in higher and higher concentration. In the final molasses, which in the tropics is thrown away by the thousands of tons, there is in the aggregate a tremendous quantity of fructose which could conceivably be recovered.

When all the manufacturing wrinkles have been smoothed out, and the girasole or dahlia tubers have been improved beyond recognition, and the public has learned to use the new queen, who will say what the limit of her uses will be, or what heavenly products of ecstatic sweetness will be developed?

Galactose

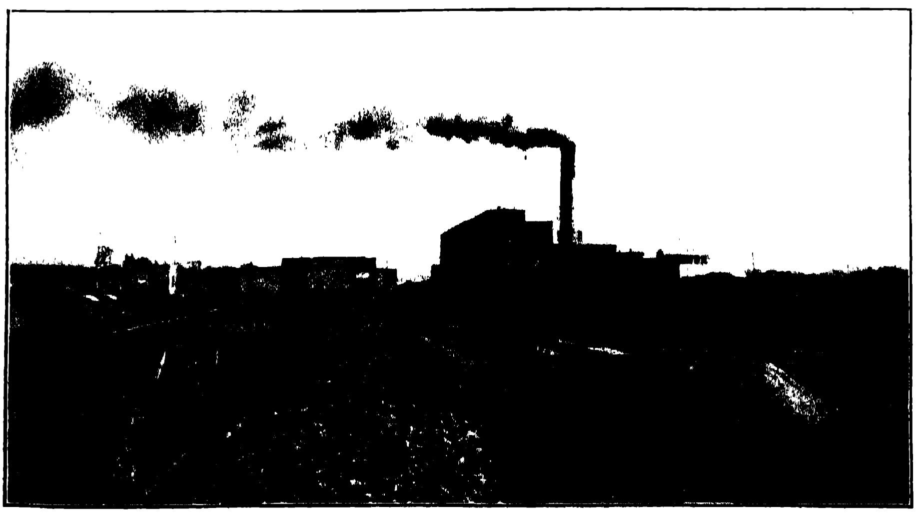
This is an unattractive, little known, un-prepossessing sugar. But it is not insignificant. It has at least two claims for greatness. One is that it constitutes half of the lactose molecule, and hence is half of the carbohydrate food of the nursing animal. The other is that it is uniformly found in brain and other nervous tissue, and hence has an integral part to perform in the functioning of our body machine. In spite of this, however, the odds are decidedly against its ever becoming a commercial sugar, for the reasons that it lacks sweetness, and that, although it is a constant constituent of nerve tissue, it apparently is not a critical sugar in our diet.

This sugar occurs as galactan in many plant materials, and notably in the wood of the western larch. Galactan holds somewhat the relation to galactose that cellulose does to glucose. Several years ago it was found that by treating the sawdust of this larch with nitric acid, the galactan could be converted to mucic acid. Mucic acid has always been just a laboratory plaything. But it can replace tartaric acid in baking powder, and this fact opens up a new possibility for the commercial utilization of galactose.

Sucrose

Sucrose enjoys the distinction of being the only carbohydrate which may legally be called "sugar." When the law says "sugar," sucrose is meant. This is a relic of the days when there was no other commercial sugar; and, with its usual inertia, the law has not changed with changing conditions, in spite of the fact that many illogical and unscientific results of this definition of sugar hamper the development of the glucose industry,

A LACTOSE FACTORY
THE COW USES PASTURE GRASS AS RAW MATERIAL FOR MAKING MILK, WHICH IS THE ONLY KNOWN SOURCE OF THE SUGAR LACTOSE.



SUGAR BEETS WAITING THEIR TURN AT THE FACTORY,
WHERE THEIR SUCROSE WILL BE EXTRACTED AND CRYSTALLIZED.

THE BEES COLLECT FLOWER NECTAR,
A DILUTE SOLUTION OF SUCROSE, AND THEN CONVERT IT INTO INVERT SUGAR. THE LATTER GIVES HONEY ITS INTENSE SWEETNESS.

and will in turn also hamper the fructose industry.

In order to show the enormity of the sucrose industry let us just mention the figure of 23,000,000 tons, which is approximately the world's consumption of this sugar as granulated sugar at the present time. A great deal more is eaten in fruits and vegetables, where it occurs very extensively. Yes, indeed, it is *the* sugar of commerce, and enormous industries are built for its production and transportation and refining and distribution, in all parts of the world. And the Congress can get up an argument over a sugar tariff as quickly as it can over the building of another man-of-war. The above figures became more impressive when the extreme purity—99.8 per cent—of these millions of tons is considered. Truly, the preparation of such a pure material, on such an enormous scale, and from such unpromising materials as was the beet a century ago and the cane two centuries ago, is a real achievement of civilization.

Sucrose is too well known to warrant any detailed discussion here. Just one phase of its chemistry may be brought out, for this phase dovetails with the discussion of glucose and of fructose above. Sucrose is a disaccharide, which means that it consists of two simple sugars combined chemically. When water is forced into the sucrose molecule chemically, the latter is split; and the two constituent simple sugars are set free. Glucose and fructose are the sugars in this case; the splitting process is called inversion, for a reason which need not concern us here; and the resultant mixture of equal parts of these two sugars is called invert sugar.

The inversion of sucrose can readily be brought about by heating it with a dilute acid. Thus when fruit jellies are made, the acidity of the fruit is quite sufficient to accomplish considerable inversion. Hence the question used to come up time and again, "Should the sugar be put in at the beginning or the end of the boiling of the fruit juice?" Some authorities said at the end, for by the inversion of the sucrose sweetness is lost. Others said at the beginning, because there would be a gain in sweetness. The correct answer is found in the table of sweetness values for the different sugars. Invert sugar is rated as 123.

There is thus a gain in sweetness. Furthermore, if allowance is made for the fact that 100 pounds of sucrose becomes 105 pounds of invert sugar, because of the chemical union of water with it, the sweetness value for inverted sucrose then becomes 130. In other words the sweetness of 100 pounds of sucrose can be made equal to that of 130 pounds by inverting it. This process is practiced to a considerable extent at the present time in the confectionery, baking and ice cream industries, and it was advocated during the war as a "sugar stretching" measure.

Lactose and Maltose

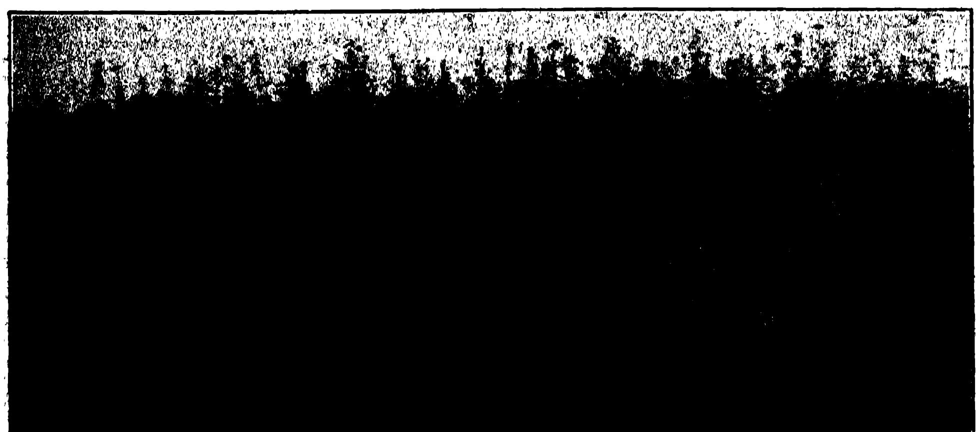
These disaccharides may well receive our sympathies. They are very useful sugars, they are beautiful sugars. But in the race for sweetness they will scarcely be granted a passing glance.

There is some compensation in this dearth of sweetness in lactose, for the dietitian is enabled to boost the caloric value of a pudding very markedly without its becoming nauseatingly sweet for a patient recovering from, say, typhoid fever. As our hygiene improves, the market for lactose for this purpose will become more insignificant than ever.

Lactose is found in milk, and it is found nowhere else in the plant or animal world. It is unique in the fluid designed for nursing mammal. And it is found in milk throughout the mammalian world—from woman down to the Australian duck bill, a mammal so primitive that it still lays eggs like a reptile.

A certain amount of milk sugar is manufactured for use in modifying cow's milk for infant feeding. Some is also used in diluting drugs for stamping into pills. A large quantity of lactose goes to waste in the buttermilk, skimmilk and whey which is thrown away in the dairy industry. It is unfortunate that some further uses have not been found for this sugar, since it is rather easily prepared, and since such quantities of it are available in wasted products. Some day research will undoubtedly find a use for it.

Maltose is a rather obscure sugar. It occurs in animals not at all, and in plants only in small amounts. The only abundant occurrence of it is in malted grain, where it arises from the starch during germination. It is prepared commercially from barley malt, and sold as a sirup. Its only devotees, however, are those who try forlornly to carry themselves back to the pre-Volsteadian days



A FIELD OF GIRASOLES,

OR JERUSALEM ARTICHOKES, WHICH, BY A NEW PROCESS, WILL YIELD 4,000 POUNDS PER ACRE OF CRYSTALLINE FRUCTOSE, A SUGAR NEARLY TWICE AS SWEET AS OUR COMMON SUCROSE.

A STRICTLY MODERN INDIAN MAPLE SUGAR CAMP
MAPLE SUGAR IS IMPURE SUCROSE, AND THE IMPURITIES CONTRIBUTE THE DELECTABLE FLAVOR TO THIS OLD FORM OF SWEETNESS.

by "rolling their own." Maltose crystallizes with some difficulty, and this, coupled with its only moderate sweetness, puts it quite out of the running as a commercial sugar possibility. Since maltose can be obtained only from starch, by hydrolysis, the latter process can better be carried to the glucose stage and sweetness thus gained.

Non-sugar Sweetening Agents

There are several artificial compounds, like saccharin and dulcin, which are far sweeter than any sugar known. They are usually considered to be several hundred times as sweet as sucrose. The greatest of them all is perillaldehyde alpha-anti-aldoxime. It is about 2,000 times as sweet as sucrose, and this, I believe, justifies its long name. They will probably, however, never be allowed to run in the race. Perhaps their synthetic origin professionalizes them, for they have no nutritive value, and were pronounced by Dr. Wiley's poison squad many years ago to be actually deleterious to health when consumed habitually. Furthermore, their sweetness is not of the same quality as that of the sugars; there is a drug-like accent to it that is not wholly agreeable.

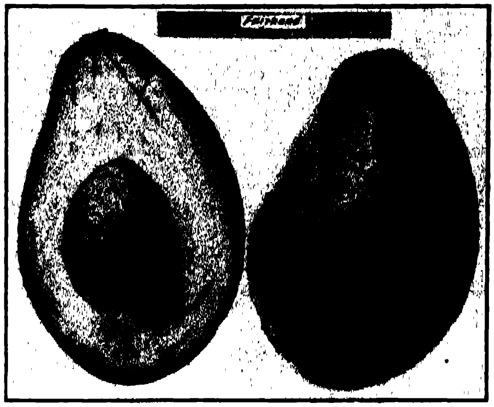
Then there are known in plants several marvellously sweet substances which are related to sugars, but which are technically glucosides. Such a one is rebaudin from Stevea, and estevin from the caa-ehe plant. The Indians gather the leaves of the latter, and dry them for sweetening purposes. Most glucosides are physiologically active, and some are used as drugs; these properties would have to be surveyed carefully before the

compound could be given further consideration for a general sweetening agent.

FUTURE SUGAR DISCOVERIES

Since, in the above list of sweetness values, only a few sugars are indicated, and since we have summarily dismissed most of them as being of little promise, a legitimate question is, "What are the chances of other sugars being discovered which might have favorable sweetness and which might be commercially developed?"

It is safe to hazard the opinion that, in the immediate future, the chance is slight. The list of sugars given above includes most of the sugars utilizable in the human body which are known to be at all widely distributed in the plant world. (Since the animal world shows surprisingly little variety in the kinds of sugars found in it, it is hopeless to look there.) Glucose, fructose and sucrose are the best in the list, and any competing stranger would have to be superior at least to glucose in sweetness, and to sucrose in abundance and in ease of preparation.



THE AVOCADO,
OR ALLIGATOR PEAR, IN WHICH HAS BEEN FOUND A VERY UNUSUAL SUGAR, THE SWEETNESS OF WHICH IS NOT AS YET KNOWN.

A BUSHEL OF CORN
THIS BUSHEL OF CORN CAN BE CONVERTED INTO ABOUT 25 POUNDS OF STARCH, OR 28 POUNDS OF GLUCOSE, OR 2 GALLONS OF ALCOHOL, BESIDES 5 POUNDS OF MOLASSES, 1 POUND OF OIL AND 27 POUNDS OF "GLUTEN" FEED.

New sugars are discovered at intervals. In 1916 a very unusual sugar containing seven carbon atoms—all ordinary sugars contain five, six or twelve carbons—was found in the avocado by investigators of the Bureau of Chemistry. If it proves to have worthy sweetness (its sweetness has not been measured); if it proves to be readily obtainable from the avocado; if it is found possible to produce a variety of the pear with a 15 per cent. concentration of this sugar; if horticulture can reduce the cost of this fruit from about 25 cents each to $10 a ton—in short, if enough of these "ifs" are satisfied, mannokeptoheptose may qualify for the race.

Again in 1917 another seven-carbon sugar was discovered in the stone-crop,

Sedum spectabile. It was named sedoheptose. Whether it can be seriously considered as a commercial sugar will depend almost altogether on the answer to the above four questions. The answers to none of them are now known.

In 1924 a still stranger sugar was found in yeast. This sugar contains sulfur. This is an extraordinary thing; it is unheard of among sugars to contain sulfur in the molecule; it simply isn't done by these aristocrats. But the ethics of the situation will never concern us, for there isn't a ghost of a chance of this thio-sugar even being considered commercially. It occurs in the minutest amounts of yeast; long and exacting labor is required even to prepare a doll's thimbleful of it; and we should have to use some kind of sugar to feed the yeast to make the new sugar.

Then, in 1923, some British biochemists isolated from cabbage a queer little three-carbon sugar, which is so queer that possibly it isn't a sugar at all. It would have been more in keeping with our expected order of things if the sulfur-sugar had been found in the cabbage. But such are the facts. The little three-carbon sugar—nameless, so far—is handicapped, like the other, in the inconsequential amounts in which it occurs. Of course cabbage has many agricultural advantages, if that were the prime consideration.

These examples of sugar discoveries are given partly to corroborate the statement that such discoveries are made from time to time, and partly to show that nevertheless such discoveries are mostly of unusual, even fantastic types of sugars, quite different from the ones which are at present well known. However, hosts and hosts of plants have not had their sugars identified and assayed. There is unlimited opportunity for research in this field. And foolish is he who would minimize or scoff at the chances of some sugar, unknown in 1927, looming large in the world of sweetness in 1950 or in 2000. And when each new discovery is made, the present writer is convinced that the first criterion to be applied will be that of sweetness. If this be unfavorable, the sugar will have to possess some unusual physiological value, such as utilization by diabetics, before it will be given further consideration.

THE PROGRESS OF SCIENCE

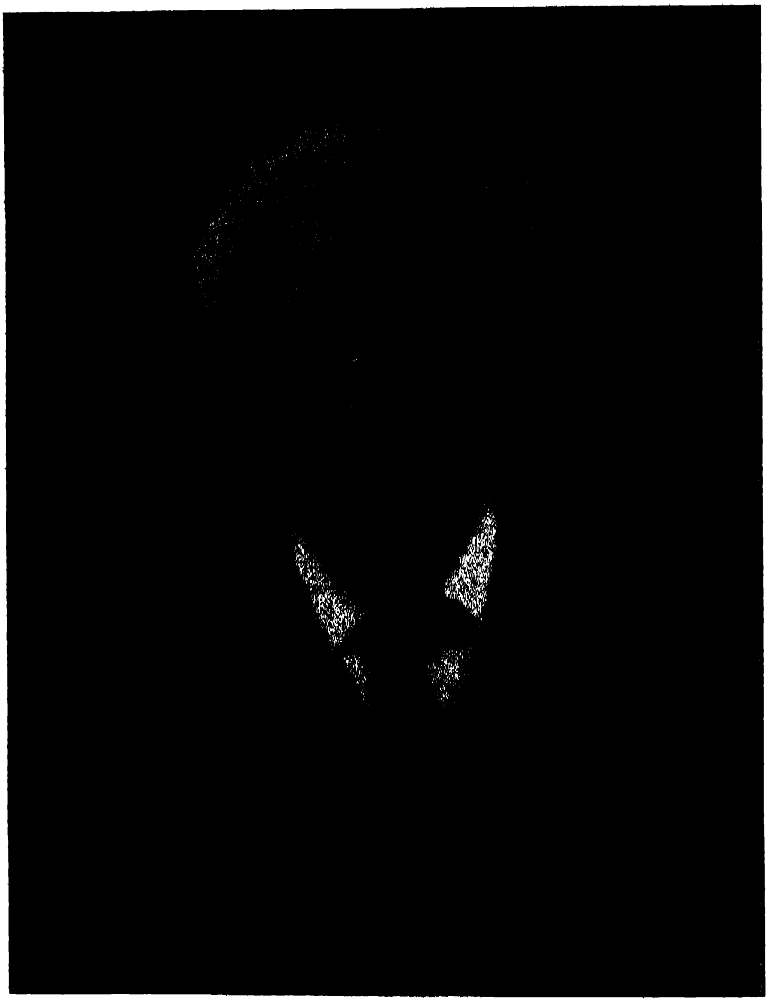
THE NASHVILLE MEETING OF THE AMERICAN ASSOCIATION

After an interval of fifty years the American Association for the Advancement of Science returns to Nashville for its eighty-fourth meeting. It has met in only three other southern cities. In 1850, two years after its foundation, the meeting was in Charleston, then a relatively more important scientific center than it is to-day. Joseph Henry, one of the world's great leaders in physics, was president, and as his successor was elected Alexander Dallas Bache, great-grandson of Benjamin Franklin, who did notable work, especially as superintendent of the Coast Survey. Bache was succeeded by Louis Agassiz, and there then followed Benjamin Peirce, James B. Dana and John Torrey, men eminent respectively in zoology, mathematics, geology and botany. There were at that time 622 members of the association, now there are over 14,000, more than twenty times as many, but it could not provide twenty men a year as distinguished as those who have been named.

Simon Newcomb, the astronomer, was president at the time of the last Nashville meeting, and Othniel C. Marsh, the paleontologist, was elected to succeed him. Here again we have men distinguished outside the limits of their science and their country. The other two meet-

COLLEGE HALL OF THE UNIVERSITY OF NASHVILLE

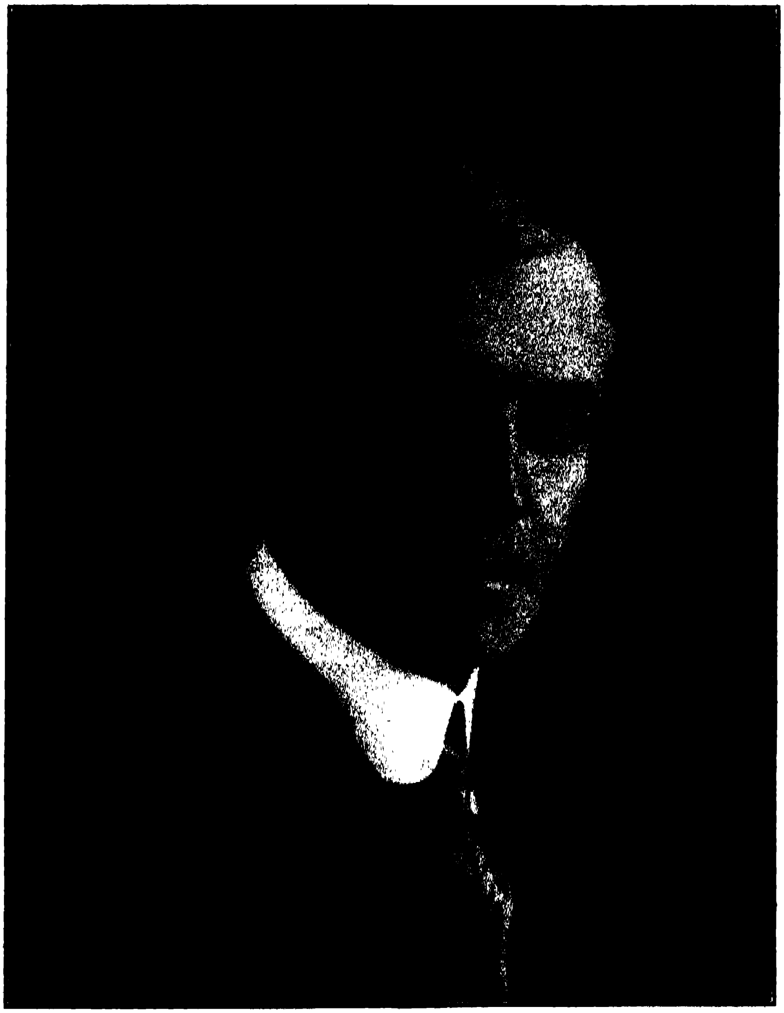
Housing the administrative offices and library, also the laboratories of physics, engineering and geology.



DR. L. H. BAILEY
RETIRING PRESIDENT OF THE AMERICAN ASSOCIATION.

ings held in the south were at New Orleans in 1904 and at Atlanta in 1913. At the former meeting the three presidents—the retiring president, who gives his annual address, the one who presides and the one who is elected—were W. G. Farlow, Harvard botanist; C. M. Woodward, St. Louis engineer, and W. H. Welch, Johns Hopkins pathologist. At Atlanta the three were E. C. Pickering, Harvard astronomer; E. B. Wilson, Columbia biologist, and Charles W. Eliot.

Fortunately the American Association is able to continue its distinguished line of succession in the presidential office. At the opening session at Nashville the address of the retiring president will be given by Dr. L. H. Bailey, distinguished as a systematic botanist, author and editor of our most valuable books on cultivated plants and rural life. Professor Arthur A. Noyes, who presides at Nashville and will make the address at the New York meeting a year hence, was for many years associated with the Massa-



DR. ARTHUR A. NOYES
President of the American Association.

chusetts Institute of Technology. In 1920 he joined Dr. W. H. Hale and Dr. R. A. Millikan in the noteworthy development of the California Institute of Technology at Pasadena, where he is director of the Gates Chemical Laboratory. Recognition of Dr. Noyes's research has just now been made by the award to him of the Davy medal of the Royal Society.

Those members of the association who attended the meetings at New Orleans and Atlanta remember them with special pleasure, for they gave insight into our broad and varied civilization. Nashville may seem remote to the provincial east, which indeed is one of its attractions, but it is not far south of the center of population of the United States. The city has long been one of the chief educational centers of the south and has enjoyed a notable development in recent years. Vanderbilt University, endowed by Cornelius Vanderbilt in 1873, now has in addition to other departments a medical school of high standing, to which the General Education Board has given

$5,500,000 and the Carnegie Foundation $1,500,000. The George Peabody College for Teachers has a national reputation, as has also Fisk University for the education of Negroes.

Edward Emerson Barnard, the eminent astronomer, was born in Nashville in 1857 and was graduated from Vanderbilt University. He made many valuable contributions to astronomy, among which may be mentioned the discovery of the fifth satellite of Jupiter. It is specially fitting that a general session at this Nashville meeting should be devoted to his memory. The address will be made by Dr. Robert G. Aitken, associate director of the Lick Observatory, retiring vice-president for the section of astronomy.

Among other general sessions is the fifth annual Josiah Willard Gibbs lecture, to be given by Professor Ernest W. Brown, of Yale University, whose subject is "Resonance in the solar system." The sixth annual Sigma Xi lecture will be by Dr. Clarence C. Little, president of the University of Michigan, who will speak on "Opportunities for research in mammalian genetics."

An evening lecture is to be devoted to a lecture on "Science and the Newspapers," by Dr. William E. Ritter, the distinguished zoologist, who has been a leader in the organization of Science Service, endowed by the late E. W. Scripps for the purpose of supplying science news to the daily press. This general session will continue and round out an all-day symposium on "Science for the People," arranged by Austin H. Clark. A general session is to be devoted to a series of papers on phases of the economic relations of science workers. This program has been arranged by the committee of one hundred on scientific research, of which Dr. Rodney H. True is secretary.

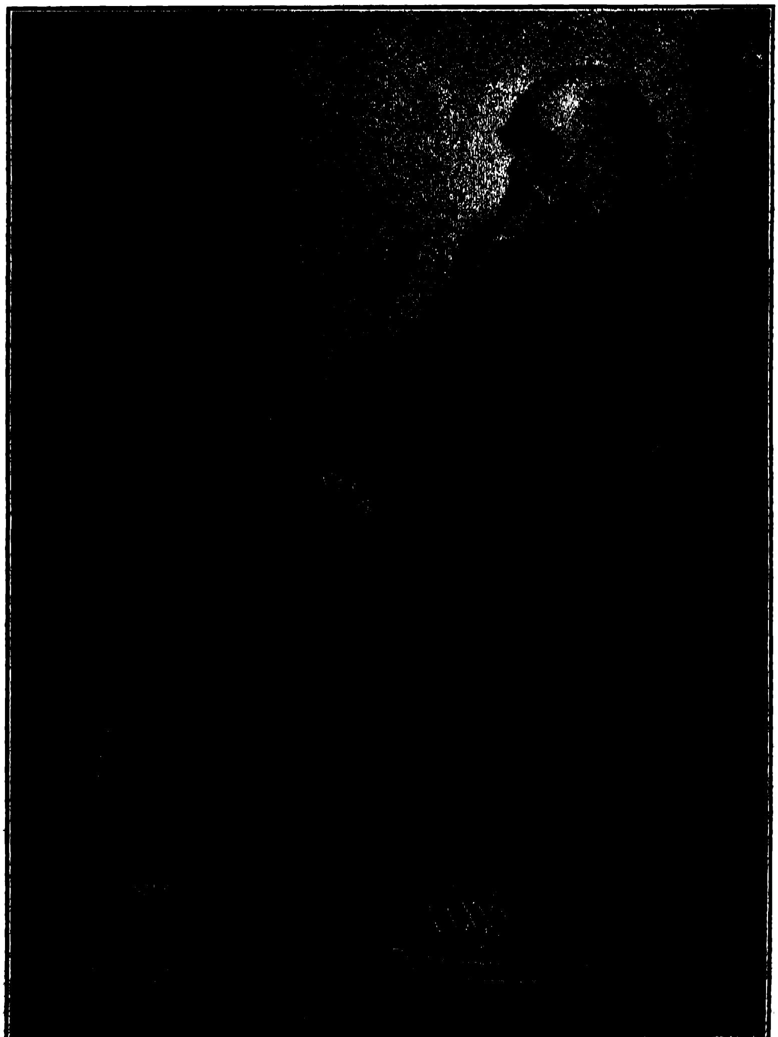
There will be popular lectures and many addresses and meetings of general interest. In addition to the sections of the association twenty-five associated societies meet with it at Nashville and there will be presented hundreds of papers, each contributing to the advancement of science.

DARWIN'S HOUSE AT DOWNE

At the recent Leeds meeting of the British Association the president, Sir Arthur Keith, announced that the council of the association was considering the possibility of purchasing for the nation the home in Kent where Charles Darwin lived for forty years. A few hours thereafter Mr. George Baxter, a retired London surgeon, telegraphed an offer to provide for the purchase of the place and for establishing a fund for its up-keep. It is understood that the donor has expressed a wish that Downe House, without and within, should be restored so far as possible to its condition in 1882 when Darwin died.

The place has remained in the possession of Professor Francis Darwin, the distinguished botanist, son and biographer of Darwin, but is now leased for a girls' boarding school. The house has not been altered radically since Darwin lived there, but the furniture has been removed and the paneling covered for its protection. A corrugated iron garage and a laundry with a concrete tennis court have been built, and it is said that the grounds and orchard have been somewhat neglected.

There have been various proposals to purchase the house at Downe (it was formerly spelled Down) since Darwin's death. At one time Adam Sidgwick and Francis Darwin were among those who proposed to secure the house for the Royal Society and use it as a biological station for the study of heredity. It is said that Andrew Carnegie offered to



DARWIN AT HOME AT DOWNE

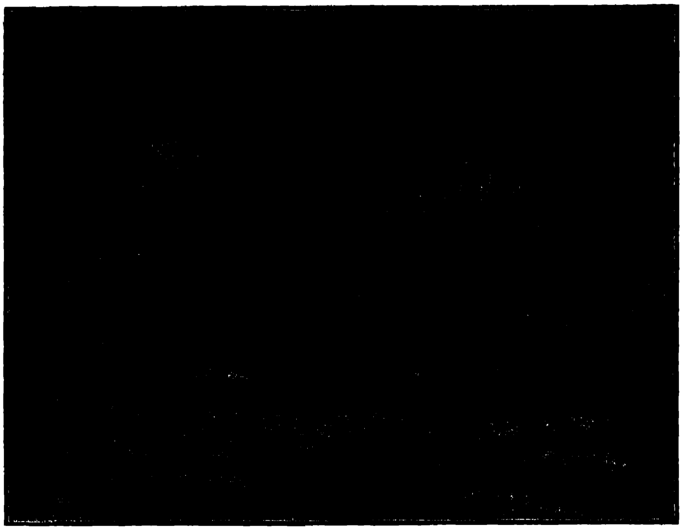
DOWNE HOUSE FROM THE GARDEN

THE ILLUSTRATIONS ARE FROM THE "LIFE AND LETTERS," THOSE OF THE HOUSE HAVING BEEN ORIGINALLY PUBLISHED IN THE CENTURY MAGAZINE.

purchase the house and provide a sum of money to settle once for all the controversy over evolution.

Darwin returned to England from the voyage on the *Beagle* in 1836, and lived in Cambridge and in London until his marriage in 1839 and for three years thereafter. He tells us that during this period he did less scientific work than during any other period in his life. He decided in the interest of his health and work to live in the country and, after several fruitless searches in Surrey and elsewhere, found the house at Downe and purchased it.

The village of Downe, though only sixteen miles from London, was remote, reached only by a coach drive of some twenty miles. The nearest railway station was ten miles distant, and at first Darwin used to take this drive with an old gardener as his coachman, who drove with great slowness and caution up and down the many hills. A little later,



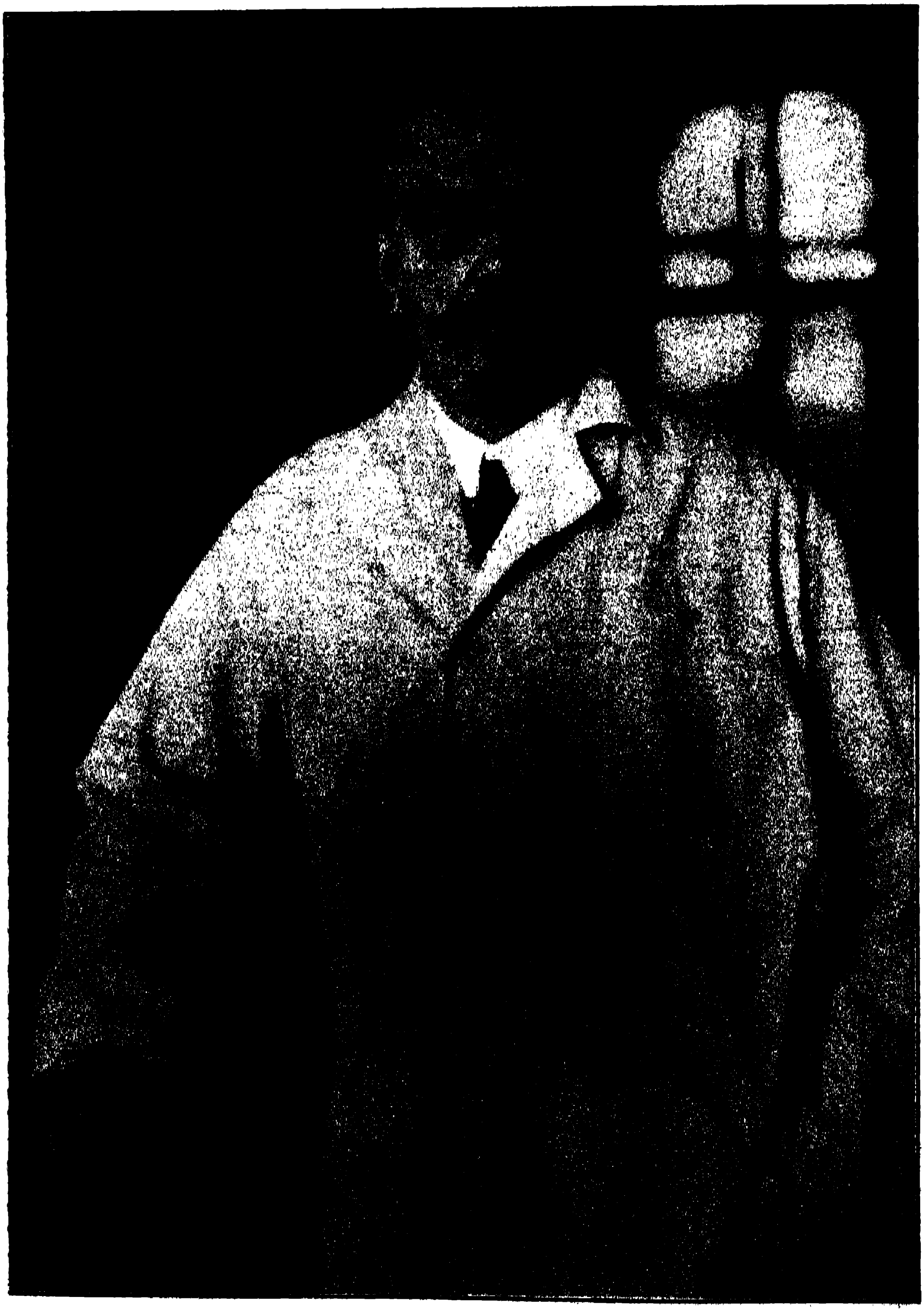
THE STUDY IN DOWNE HOUSE

owing to his health, he ceased to attend scientific meetings in London. Though railways are now closer, Downe is still out of the world, being three miles from the nearest station.

As Sir Francis Darwin tells us in the "Life and Letters," the village stands on a solitary upland country, five to six hundred feet above the sea. The country has little natural beauty, but possesses a certain charm in the strips of wood capping the chalky banks and looking down on the ploughed lands of the valleys. The village has three or four hundred inhabitants with a little flint-built church.

The house stands one quarter of a mile from the village and is close to the road. When purchased by Darwin it was a square brick building of three stories, covered with shabby whitewash. The ground was open, bleak and desolate. After its purchase the house was covered with stucco and enlarged on several occasions. The grounds were planted and from the eighteen acres of land that were bought with the house a shrubbery was cut off, which ultimately became an experimental plot where greenhouses were put up. Darwin himself in a letter to Mr. Fox, written in 1843, gives his early impressions of Downe as follows:

We are now exceedingly busy with the first brick laid down yesterday to an addition to our house; with this, with almost making a new kitchen garden and sundry other projected schemes, my days are very full. I find all this very bad for geology, but I am very slowly progressing with a volume, or rather pamphlet, on the volcanic islands which we visited; I manage only a couple of hours per day and that not very regularly. It is uphill work writing books, which cost money in publishing, and which are not read even by geologists. I forget whether I ever described this place; it is a good, very ugly house with 18 acres, situated on a chalk flat, 560 miles above sea. There are peeps of far distant country and the scenery is moderately pretty: its chief merit is its extreme rurality. I think I was never in a more perfectly quiet country. Three miles south of us the great chalk escarpment quite cuts us off from the low country of Kent, and between us and the escarpment there is not a village or gentleman's house, but only great woods and arable fields (the latter in sadly preponderant numbers), so that we are absolutely at the extreme verge of the world. The whole country is intersected by foot-paths; but the surface over the chalk is clayey and sticky, which is the worst feature in our purchase. The dingles and banks often remind me of Cambridgeshire and walks with you to Cherry Hinton, and other places, though the general aspect of the country is very different.



PROFESSOR JOHANNES FIBIGER

PROFESSOR FIBIGER'S WORK ON THE EXPERIMENTAL PRODUCTION OF CANCER

PROFESSOR JOHANNES FIBIGER, director of the Pathological Institute of the University of Copenhagen, has been awarded a Nobel prize for physiology and medicine. Although his investigations were begun in 1907, the initial difficulties were so great that his first account did not appear until 1912. The interval was devoted to a piece of detective work as brilliant as any to be found in fiction, the only counterpart of which, in modern medicine, is the apprehension of "Typhoid Mary" by Soper.

In the year 1907, then, Fibiger was engaged in the study of tuberculosis, and in the course of his work had occasion to autopsy three wild rats. In the mucous membrane lining the prostomach of each he found an intense thickening of the epithelium, which at certain points had progressed to the formation of warty outgrowths. The process appeared to be a fibro-epithelial tumor, possibly of malignant character; its cause, a parasitic worm belonging to the Nematode group.

A lesion of the stomach such as this had not been previously described in rats, nor was the accompanying worm familiar to zoologists. In order to learn something of the nature and occurrence of this unknown disorder, Fibiger examined the stomachs of 1,144 rats from various sources, but found neither the Nematode nor the disease which he was seeking, and he was unable to transfer the latter to other rats by inoculating or feeding the affected tissue. For the average man this would have sufficed; but those who win a Nobel prize are not average men.

Attempts to transmit the disease by feeding experiments having failed, Fibiger began to consider the possibility that his parasite was not directly transferable from rat to rat, but required the intervention of another host. Now it had long been known that a cockroach (*Periplaneta orientalis*) is the intermediate host for a similar worm, also an inhabitant of the rat's stomach, and Fibiger therefore examined wild rats from a locality in Copenhagen that was swarming with this pest, but found neither Nematode nor hyperplasia. Transmission experiments, also, were disappointing, for rats fed with the roach remained in good health.

A more encouraging result attended the search in rats from a large sugar refinery, where a different cockroach (*Periplaneta americana*) ruled. Within about nine months, sixty-one rats were caught in this building, and in forty of them the long-sought Nematode was found, while in no less than eighteen of these forty the strange hyperplastic disease was a concomitant feature of the infestation. Rats fed with the *americana*, too, developed the characteristic changes in the stomach, and in some the disease had actually progressed to the inception of cancer. There could no longer be any doubt that the disease depended upon the presence of the parasite or that *Periplaneta americana* was the intermediate host; indeed, the larval stage of the worm was easily demonstrable in the muscles of the insect.

The experimental production of cancer had at last been achieved. That is the great and enduring value of Fibiger's work, the major part of which has now been told, and it remained only to consolidate and amplify his basic observations. There followed in due course a technical description of the parasite, for which the name *Spiroptera neoplastica* was chosen, and an account of investigations in which problems were attacked that had never before been susceptible of experimental approach. It was now possible to discover the period required for the inception of cancer,

which was found to be at least six weeks, and to inquire into the importance of age. Rather unexpectedly, age turned out to be a less decisive factor than clinical experience had suggested, for rats weighing but thirty grams at infestation proved readily susceptible. Hence it appeared that the length of time over which the irritant had acted was more important than age in the etiology of carcinoma.

The manner in which the parasite produces the cancer is still a mystery. True enough, inflammation was an almost constant feature in infested stomachs, but no relation was discoverable between the degree of inflammation and the development of cancer, an observation which has since been substantiated in other types of experimental new growth. The active agent seemed to be some sort of poisonous secretion of a nature entirely unrecognized, rather than a specific cancer virus.

Had this work been accomplished ten years before it was, there is no doubt that it would have been more loudly acclaimed. But not only did the war withdraw all interest from cancer research; in the meantime there had been discovered, in Japan and in America, two other ways of inciting malignant tumors, one of them much less laborious than Fibiger's. His method, accordingly, instead of standing unique, as it well might have done for a time at least, became only one of three means to the desired end. But this does not lessen the value of his work, which will remain an enviable model of shrewd observation and patient experiment.

W. H. W.

THE SCIENTIFIC MONTHLY

FEBRUARY, 1928

TWO EXPEDITIONS AFTER LIVING PLANTS

THE ALLISON V. ARMOUR EXPEDITIONS OF 1925–27, INCLUDING TWO VOYAGES IN THE ESPECIALLY EQUIPPED YACHT UTOWANA[1]

By DAVID FAIRCHILD

OFFICE OF FOREIGN PLANT INTRODUCTION, U. S. DEPARTMENT OF AGRICULTURE

MOST botanical expeditions in the past have been for the purpose of discovering new species of plants which would broaden the horizon of botanical knowledge. The Allison V. Armour expeditions, of which this is the first description to be published, were for the purpose of collecting the living seeds and plants of any species, whether wild or cultivated, described or new, which appeared likely to have any definite use when cultivated in America. They might properly be considered as expeditions in the interest of the work of plant introduction of the United States Department of Agriculture and resembled in kind previous expeditions which the late Barbour Lathrop, of Chicago, financed during the years between 1898 and 1903, on which I acted as agricultural explorer.

The period covered by the Allison V. Armour Expeditions was from September, 1924, to April, 1927, and the regions visited included the following countries: England, France, Belgium, Holland, Switzerland, Sweden, Germany, Italy, Spain, Portugal, Algeria, Morocco, Ceylon, Sumatra, Java, the Straits Settlements, the Canary Islands, the Balearic Islands, Gambia, Senegal, French Guinea, Sierra Leone, Liberia, the Gold Coast, the Cameroon, both French and British mandated territory.

Only a limited time was spent in any one country—the object being primarily to get in touch with the scientific plant men of the various countries; to make arrangements for a plant exchange with them, and at the same time secure what plant material was immediately available for introduction into America.

The following scientific men were at one time or another associated with me as the guests of Mr. Armour, either on his yacht *Utowana*, or on various collecting trips by automobile and truck into the interiors of the less well-known regions visited.

Dr. William Morton Wheeler, of Bussey Institution, Harvard University, whose work was exclusively with insects; my colleague, Mr. P. H. Dorsett, of the Office of Foreign Plant Introduction, of the Bureau of Plant Industry, Department of Agriculture; Dr. H. H. McKinney, plant pathologist of the office of Cereal Investigation, Bureau of Plant Industry, U. S. Department of Agriculture, whose work was mainly with the

[1] Unless indicated to the contrary the photographs have been taken by David Fairchild.

THE YACHT *Utowana* AS SHE LAY IN THE HARBOR OF STA IZABEL FERNANDO PO, WITH HER STARBOARD LAUNCH BRINGING PASSENGERS ASHORE. THE ARRIVAL OF THE BEAUTIFUL WHITE BOAT IN THESE HARBORS OF THE WEST COAST OF AFRICA WAS GENERALLY SOMETHING OF AN EVENT. SHE IS HERE SHOWN IN COMPARISON WITH A TRAMP STEAMER SUCH AS COMMONLY PLIES UP AND DOWN THE COAST. NO YACHT HAS EVER BEEN MORE COMPLETELY FITTED UP FOR COLLECTING WORK THAN WAS THE *Utowana.*

virus diseases of plants; Dr. J. M. Dalziel, of the Kew Herbarium, coauthor with Dr. Hutchison, of the New Flora of West Africa, who in addition to his botanical work acted as medical officer of the yacht. Acting as photographers and general assistants, J. H. Dorsett, Fred W. Schultz and my son Graham Bell Fairchild, were attached to the various expeditions. Mrs. Fairchild accompanied the expedition to Morocco and the Orient and contributed much to its success there.

The technique of this type of exploration work is perhaps better understood by horticulturists than by botanists, for it involved the transport, for purposes of propagation, of living seeds and cuttings from one country to another. The classic examples of this kind of exploration work are furnished by such voyages as that of Lieutenant Bligh, on H. M. Ship *Bounty* to Tahiti, to secure the seedless breadfruit tree; and the voyage of Wickham in 1876 to Brazil after the Para Rubber Tree (*Hevea Braziliensis*), which resulted in the former case in the cultivation of the breadfruit tree in the West Indies, while Wickham's made possible the gigantic plantation rubber industry in the Orient.

The yacht *Utowana*, which Mr. Armour had equipped especially for collecting purposes, embodies some novel equipment, such as a well-lighted laboratory for microscopical work; a delightfully arranged library with desks and bookshelves; a dark room; a special device for drying seeds and specimens; a deck to hold Wardian cases on and

ample storage space for supplies of all sorts.

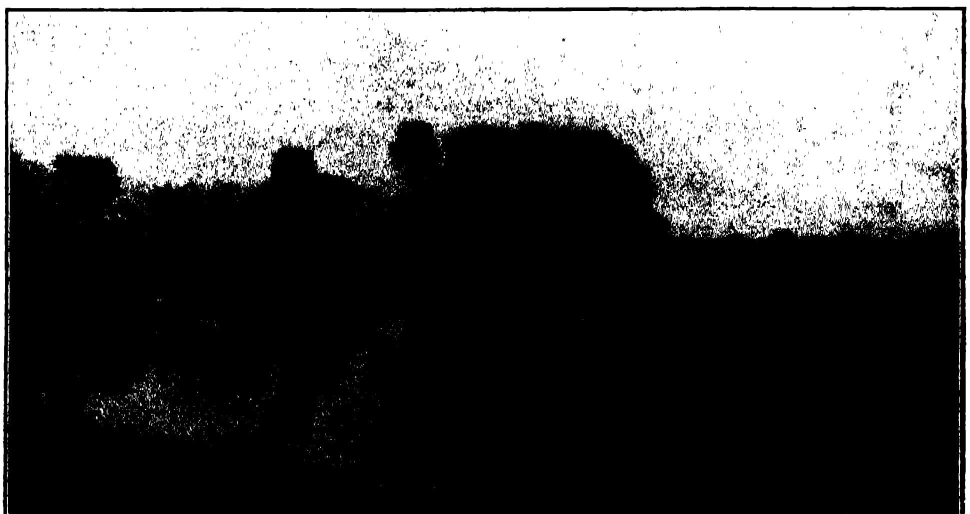
Two launches furnished the means for getting on shore and a crew of 30 men ran the yacht. The *Utowana* is a boat of 1,315 tons weight; 230 feet in length; 33 ft. 10 inch beam; 11 to 12 ft. draft, provided with two Atlas Diesel 500 H. P. engines, capable of pushing it 10½ knots an hour through the water and it has complete electrical equipment; a cruising radius of 12,000 sea miles; water tanks holding 200 tons of water, and space in its cold storage rooms for provisions to supply an excellent and varied menu for a six months cruise.

The original intention was to visit the Moluccas and the plans were made to do this in 1925, but quite unexpected delays in the completion of the remodeling of the yacht were met with in the winter of 1924–25, and instead of her being ready to sail in December, 1924, she was not in the water until May of 1925.

During these months of delay I was able to look up many matters of importance in various of the herbaria of Great Britain and Europe and carry out a three months' collecting trip in our own car in Algiers and Morocco accompanied by Mrs. Fairchild, Dr. W. M. Wheeler and my son Graham.

The yacht arrived at Casa Blanca in May with Mr. Armour and Mr. and Mrs. Jordan Mott on board and we made a trial cruise through the Canary Islands and Balearic Islands preparatory to the Molucca trip which was scheduled to start October, 1925.

On the eve of departure from Naples, however, the *Utowana* developed serious engine trouble which eventually made Mr. Armour abandon taking her to the Dutch East Indies and the expedition went on by regular steamer. Mrs. Fairchild, Graham and I were joined in Ceylon by Mr. Dorsett and his son who had been exploring for plants in Man-



THERE IS AN INDESCRIBABLE CHARM ABOUT THE GAMBIA RIVER REGION AS WE SAW IT IN THE EARLY MORNINGS FROM THE DECK OF THE YACHT. IT WAS THE WINTER SEASON, THE AIR WAS FRESH AND WE HEARD AN EXTRAORDINARY NUMBER OF BIRDS. THE TREES WHICH DOT THE PLAIN ARE THE SILK COTTON, MANGO, RHUN PALM (*Borassus æthiopum*) AND, IN THE DISTANCE ON THE RIGHT, THE DOUM, OR GINGERBREAD PALM (*Huphaene thebiaca*) WHICH HAS THE CHARACTER, UNIQUE AMONG PALMS, OF POSSESSING NORMALLY A BRANCHING TRUNK.

STRIPPING BARK FOR ROPE-MAKING FROM A BAOBAB TREE IN THE GAMBIA. THE GIANT ANTEDILUVIAN TREES OF THIS *Adansonia digitata,* WHICH ARE SCATTERED OVER THE PLAINS ON EITHER SIDE OF THE GAMBIA RIVER, ARE CURIOUSLY SCARRED FROM HAVING HAD THE BARK REMOVED IN THE WAY SHOWN. FOR CENTURIES THE INHABITANTS HAVE MADE THEIR ROPES OF THIS FIBROUS BARK. WHEN A NATIVE WANTS A ROPE HE GOES TO A TREE INSTEAD OF TO A STORE.

churia for the Department of Agriculture, and who had been invited by Mr. Armour to form a part of the expedition to the Moluccas.

After two months in Ceylon we left on February 13 for Sumatra where we stayed until March 31 doing more or less intensive collecting work. We purchased a car with which we were able to traverse the excellent roadways of North Sumatra and pentrate into the region about Lake Tawar—which is one of the most remarkable and least visited regions of all Sumatra—with a flora that is very imperfectly known and jungles which rival in beauty and mystery any I have ever seen anywhere.

Through the courtesy of the Governor of Sumatra who put us in touch with Mr. Brandts Buys, the head forester of

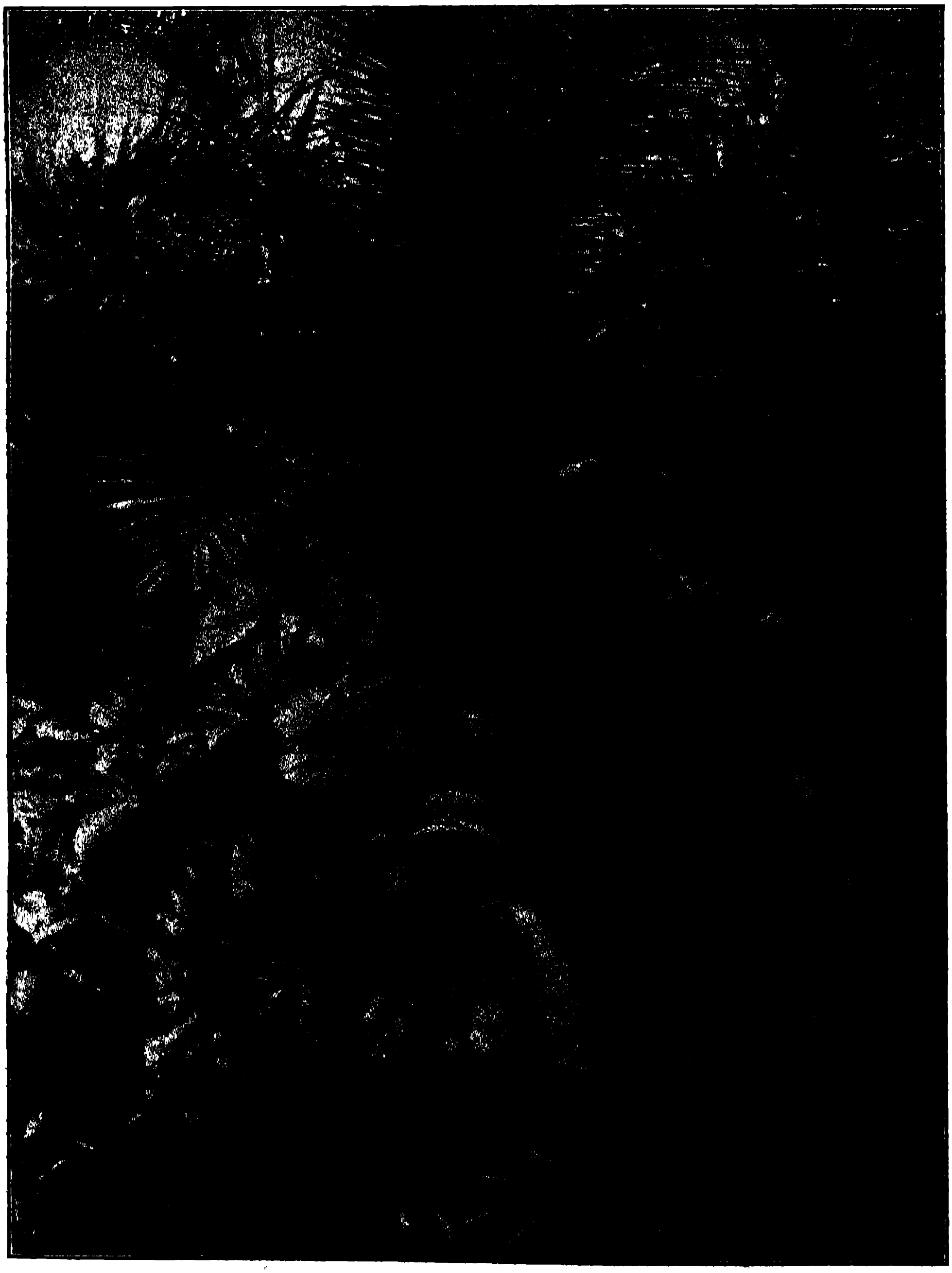
the island, we were able to organize a collecting journey of two weeks duration covering a distance of jungle trail over two hundred miles long directly through the virgin forests of Atcheen. This wonderful two weeks trip was made on foot by Mr. Dorsett and his son, and my son Graham without encountering any difficulty with the Atchenese, even though the day before they started, a massacre of Dutch troops had taken place on the West Coast some fifty miles only from the line of march. This was the first of one of those short series of outbreaks which have characterized the behavior of the Atchenese toward the Dutch for the past half century, and has not in my opinion the particular significance from the Moscow standpoint, which has been attributed to it by sensational writers in American journals.

The expedition did some of its most interesting collecting work in one of the most remarkable botanic gardens in the world. It would be hard to find, I believe, any region in the tropics which is to-day more interesting as a collecting field than that of the Sumatran highlands, a plateau comprising more than a million acres of virgin grass land penetrated by deep jungle-covered valleys and all lying from 3 to 4,500 feet above sea-level where the climate is drier by 20 per cent. than that common to mountain peaks in the tropics (20 per cent. drier than Newara Eliya, Ceylon, for example) and where until fourteen years ago cannibalism existed. From Sumatra we left, March 31, for Java, and, after spending several weeks in the region about Buitenzorg, motored across the island, collecting mainly cultivated plants in the densely settled portions of that remarkable island. We had a glimpse of that most extraordinary plant, *Rafflesia patma,* which has flowers sixteen inches across, and which occurs abundantly on the Convict Island of Noesa Kambangan; we visited the Djeng Plateau, the oldest center of prehistoric civilization in Java; the central Sultanates of Djokja and Solo and the hot dry region of East Java. In April the Dorsetts returned to their collecting work in Manchuria and in June the rest of us went back to Europe *via* Egypt.

In the meantime Mr. Armour had taken the *Utowana* to Stockholm to equip her with new engines and cabled us that he would be ready in December to undertake a trip down the West Coast of Africa. Accordingly in the fall a new staff of scientific men for the West African trip was gotten together in Washington, and early in December, Mr. and Mrs. Francis Whitehouse, sister and brother-in-law of Mr. Armour; my assistant, F. W. Schultz, and I sailed for Gibraltar. There we met Mr. Armour on the yacht *Utowana* with her new engines installed and with Dr. Dalziel and Dr. McKinney already on board.

Leaving Gibraltar on the eighteenth of December, we spent Christmas in Teneriffe and left for the Gambia River on the last day of the year 1926. The following itinerary of the yacht *Utowana* indicates the character of the cruise down the West Coast of Africa which, while it admitted of no prolonged stay in any one place, afforded a unique opportunity for comparisons to be made of the floras and climates and civilization, so called, of the European Colonies on this great West African Coast.

The winter season from November to April is the only one in which a small yacht could navigate the waters of this coast and land passengers with any degree of certainty, owing to the absence of harbors and the high surf, which has to be crossed in special surf boats, paddled by gangs of Kroo boys. The almost complete absence of hotels, furthermore, complicates any prolonged work on shore.



A BEAUTIFUL GIANT AROID OF THE CAMEROON (*Cyrtospermum senegalense*). DR. DALZIEL, OF THE EXPEDITION, IS STANDING IN A PATCH OF THIS AMAZING AROID WHICH COVERED A QUARTER OF AN ACRE. THE TWO-FOOT SPATHES ARE RAISED TEN FEET INTO THE AIR ON SQUARE ANGULAR SPINY STALKS. THERE ARE LARGER AROIDS THAN THIS BUT NONE WHICH GROWS IN MASSES OR MAKES A MORE STRIKING SHOW. FOUND BACK OF DUALA, CAMEROON.

Itinerary of Cruise

	Arrived		Left	
Bathurst, Gambia	Jan.	4	Jan.	12
Konakry, French Guinea	"	15	"	17
Freetown, Sierra Leone	"	17	"	26
Monrovia, Liberia	"	27	"	28
Sta Isabel, Fernando Po	Feb.	3	Feb.	4
Duala, Cameroon	"	4	"	8
Victoria, Nigeria	"	8	"	21
Accra, Gold Coast	"	24	"	26
Takaradi, Gold Coast	"	27	March	2
Konakry, French Guinea	March	7	"	12
Dakar, Senegal	"	14	"	17
Las Palmas	"	20	"	23
Gibraltar	"	27	April	1
Lisbon	April	6	"	10
Bordeaux	"	13	"	17

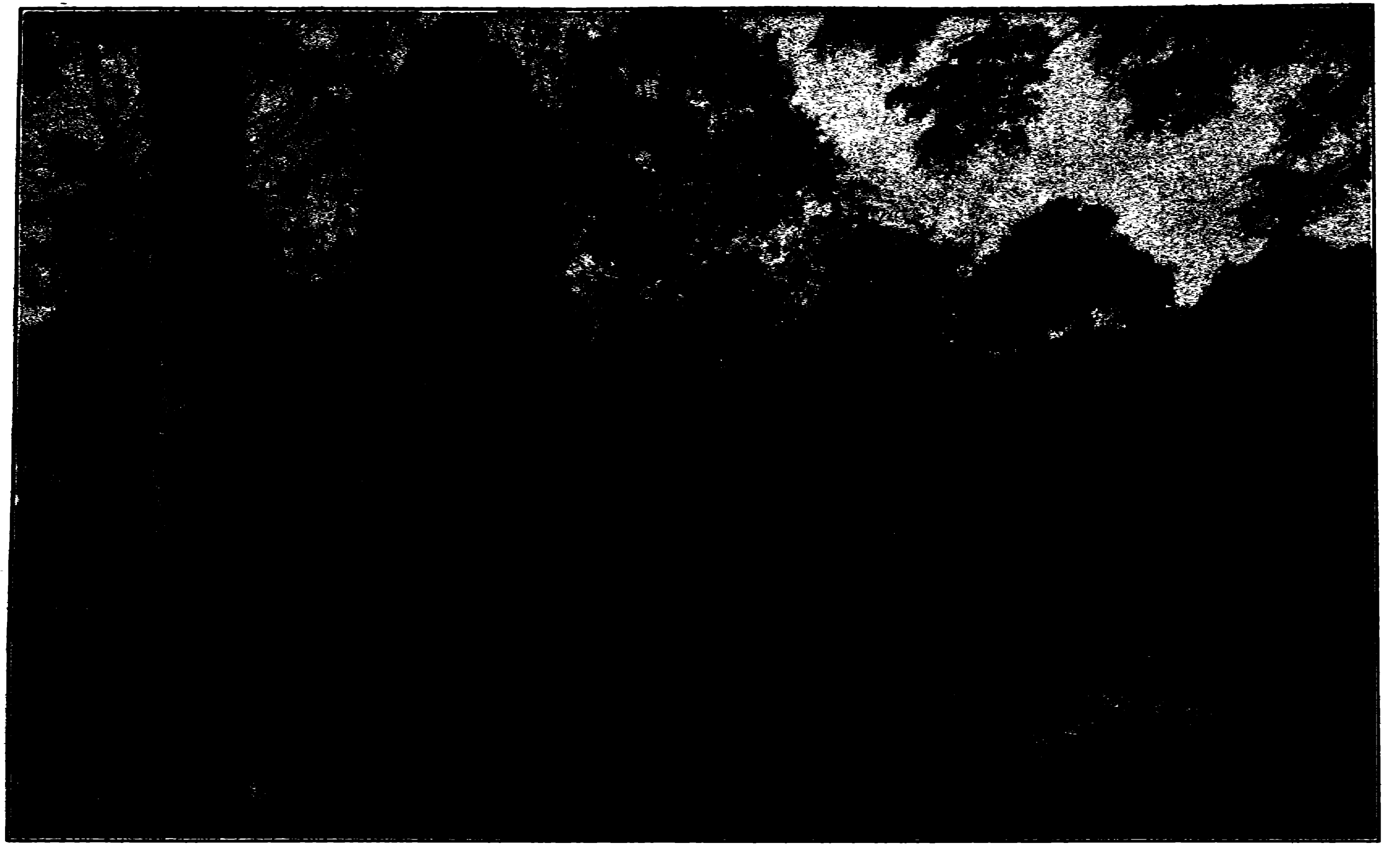
Transportation on the West Coast of Africa is improving rapidly with the building of networks of good roads and the importation of hundreds of small but high-powered automobiles. Soon it will be possible to reach almost any of the important regions by automobile, but at present any general view, such as we had, would be practically impossible without a special boat. The natives are so thoroughly infected with malarial parasites that prolonged stay in West Africa exposes any exploring party to the West African fever, but we were there during the best season of the year when there were almost no mosquitoes about and thanks to our isolation on the yacht only one of our party suffered from fever.

Ordinarily the results of botanical collecting trips can be measured by the numbers of specimens collected and the number of new species discovered among these specimens. These latter represent positive new scientific data. Such a yardstick as this, however, is in no way applicable to plant introduction work, for here we deal with a transferring of plants from one country to another, not with the discovery of new species of plants. Furthermore, numbers of plants collected do not tell the story, for those which arrive dead represent futile attempts. A more reasonable measure of the results would be through an account of the successful growth of the species of plants introduced. But here again enters another difficulty—the time element. Plants grow so slowly that years must pass before one can know whether seeds transplanted from one region will grow and produce in another. In 1876 Hevea seeds were sent from Brazil *via* Kew to Ceylon. A year after this introduction was made there were only tiny seedlings to show that the Brazilian immigrant would grow in its new environment. Twenty years later only a few men like Ridley, of Singapore, believed that this Brazilian rubber tree was to be a commercial success in the Orient, and although to-day billions of dollars are invested there in the rubber plantations which grew from the seeds of those trees—half a century of time has passed and the actors in the drama are most of them dead.

Perhaps it were better in writing of this kind of an expedition to look upon the introduction from a foreign country of a plant new to the country into which it is sent, as the procuring of the materials for an experiment. The experiment is successful only when that plant comes into some use or other somewhere in that country.

As a result then of our expeditions we have brought in as experimental material some 1,400 species of plants and made about 2,500 photographs of plant industries and nothing short of a two-volume book could adequately describe these results of two and a half years of plant collecting in Europe, Africa and Asia.

A brief summary is possible, however, and it will perhaps serve the purpose of placing the expedition in historical literature, so that those later who study the dried specimens which were collected or who grow the living plants can at least find out where the expedition went



—*Photo by F. W. Shultz*

VIEW IN THE BOTANIC GARDENS OF VICTORIA, CAMEROON. THIS IS THE MOST EXTENSIVE BOTANIC GARDEN ON THE WHOLE WEST COAST OF AFRICA. IT WAS BUILT UP BY PROFESSOR P. PREUSS AND UNTIL THE WAR WAS CAREFULLY MAINTAINED. EVEN NOW, AFTER YEARS OF NEGLECT, IT REMAINS ONE OF THE GREAT COLLECTIONS OF TROPICAL TREES AND PLANTS. A NEW DIRECTOR HAS JUST BEEN SENT OUT FROM KEW, AND IT IS HOPED THAT HE WILL BE ABLE TO BRING IT BACK TO THE CONDITION IN WHICH IT WAS UNDER GERMAN SUPERVISION.

and where it did its work in the various countries visited. The dried specimens collected and the photographs made will be found either in the herbarium of the Office of Foreign Plant Introduction in the Bureau of Plant Industry in Washington or in the Kew Herbarium.

Of the personal characteristics of the big-hearted man whose conception it was to equip a yacht which would be of real use in the search for useful plants, I find it very hard to write, because he belongs to that very rare class of human beings to whom the doing of things that are worth while, rather than the talking about what you have done, is a deep-seated instinct. To compliment him to his face embarrassed him, and I have the feeling that to do it in print will be quite as embarrassing, although as a matter of fact I know of no man in the whole world who could have distinguished himself more completely for downright unparalleled unselfishness in everything which he did to make the cruise of the *Utowana* a success. His passion for making conveniences which he thought the scientific staff needed went so far at times that it took him into the boiling hot hold of the yacht in the hottest part of the Tropics where he had fitted up his own particular shop and where he kept his own kit of tools. I doubt if there was ever a cruise where the guests were made more thoroughly comfortable or where the personal equation was more perfectly under control than it was on the cruise of the *Utowana* down the West Coast of Africa.

As for the so-called unscientific staff—composed alternately of the Motts and the Whitehouses—it did everything possible to further the work of the expedition.

Relatives of the Mangosteen

The work of the expedition started in the Herbaria of Kew, Paris, Leiden and Geneva (Conservatoire de Botanique) with an examination of the material belonging to the genus *Garcinia*, which revealed the existence of over a hundred species having more or less edible fruits and supplied the data requisite for a systematic search for the seeds of the promising relatives of the Mangosteen (*Garcinia mangostana*), *i.e.*, promising as new fruits or as a stock for this famous fruit tree of the Orient.

The data secured will enable visits to be made to the original localities where the various dried specimens were collected, but as these localities are scattered from South America to New Guinea, and include localities which are peculiarly isolated, and since these localities must be visited at the right season, and since the shipment of living Garcinia seeds is a precarious undertaking anyhow, the work of assembling even a majority of the one hundred and thirty promising Garcinia species in any single tropical Arboretum assumes the dimensions of a life-long problem. Seeds of ten species were, however, located in Ceylon, Sumatra, Java and West Africa and sent to America for experimental use. Contrary to a hope that some really rapidly growing species might be found, I was disappointed to discover that none of the ten studied grow much faster than the mangosteen itself. The great beauty of the Garcinia trees makes them valuable, however, as dooryard and park trees wherever they can be grown, and those introduced may beautify the parks and gardens of Panama, Porto Rico, Hawaii and Cuba, and furnish material for the plant breeders later on and be used as stocks upon which to grow the mangosteen.

Burr Clovers and Other Leguminose Plants

The success which has attended the introduction of the Mediterranean species of burr clovers (*Medicago* sp.) into California and some of the Southern

States made it seem worth while to collect in the Canary Islands, Morocco, Algeria, Southeastern Spain and the Balearic Islands all the species possible for the purpose of testing them further in our own South and West.

The various species of the genus play a remarkable rôle in the enrichment of the soil and the maintenance of the sheep and goat forage of the whole Mediterranean basin. The roadway ditches, the calcareous hillsides, the fruit orchards, the sandy soils of the cork oak forests, the rocky sides of the Barrancos and even the sandy areas that skirt the seashore are everywhere inhabited by one or more species of this remarkable genus. Their nutritious stems furnish an immense amount of forage during the spring or rainy season and their nodules add nitrogen to the soils, and when the dry season arrives the millions of seed pods which they produce furnish a highly concentrated food for the sheep and goats which everywhere in this region range the roadways and dry hillside pastures.

During our visits to Ceylon, Sumatra and Java rather large collections of leguminous plant species were put at our disposal by the experimenters of the various agricultural institutions with which the British and Dutch colonies are now so well supplied. Whereas these had been made for the purpose of studying the effects of ground covers in the rubber and tea plantations, to stop erosion and add nitrogen to the soil, there is little doubt but that among those which were presented to the expedition some will prove of distinct value in the southern states of America.

European Collections

The collection of recently introduced plants which are to be found in European botanic gardens and Arboreta furnished much interesting material for

Dr. Sawyer and Dr. Wolcott, of the Rockefeller Institute, touring the Gold Coast in their search for the causes and remedies of what is called yellow fever in West Africa. Dr. Wolcott has the distinction of being the only white man who dares to wear a felt hat out there. It has long been a fixed idea that only a pith helmet will protect one from the sickening glare of the sunlight of the Gold Coast, which has the local reputation of being much more deadly than the sunlight of the Oriental tropics.

Euphorbia resinifera IN BLOOM ON THE HILLSIDES NEAR DEMNAT, MOROCCO. THEIR MASSES OF YELLOW FLOWERS CAN BE SEEN A HALF MILE AWAY AND ALTOGETHER THEY FORM ONE OF THE MOST STRIKING PLANT SIGHTS IN MOROCCO. THE LATEX OF THIS SPECIES IS HORRIBLY ACRID AS MY SON, GRAHAM, ACCIDENTALLY FOUND OUT. DR. W. M. WHEELER AND GRAHAM FAIRCHILD COLLECTING INSECT VISITORS TO THE FLOWERS.

introduction, for, although it might be supposed that a plant which once finds its way from the wilds into a European botanic garden is really "introduced" into general culture, this is really not the case. There are hundreds of species represented by single specimens in botanic gardens which are utterly unknown to the so-called nursery trade, much less to American amateurs. Only actual visits to these old mines of living plant material can disclose their existence, for often species that do poorly in the cooler moister summers and milder winters of Europe are the very ones which do best in the hot-summer-cold-winter climate of America. What is a virtual failure in Europe, one which would not be mentioned in any European literature, may prove a great success in America.

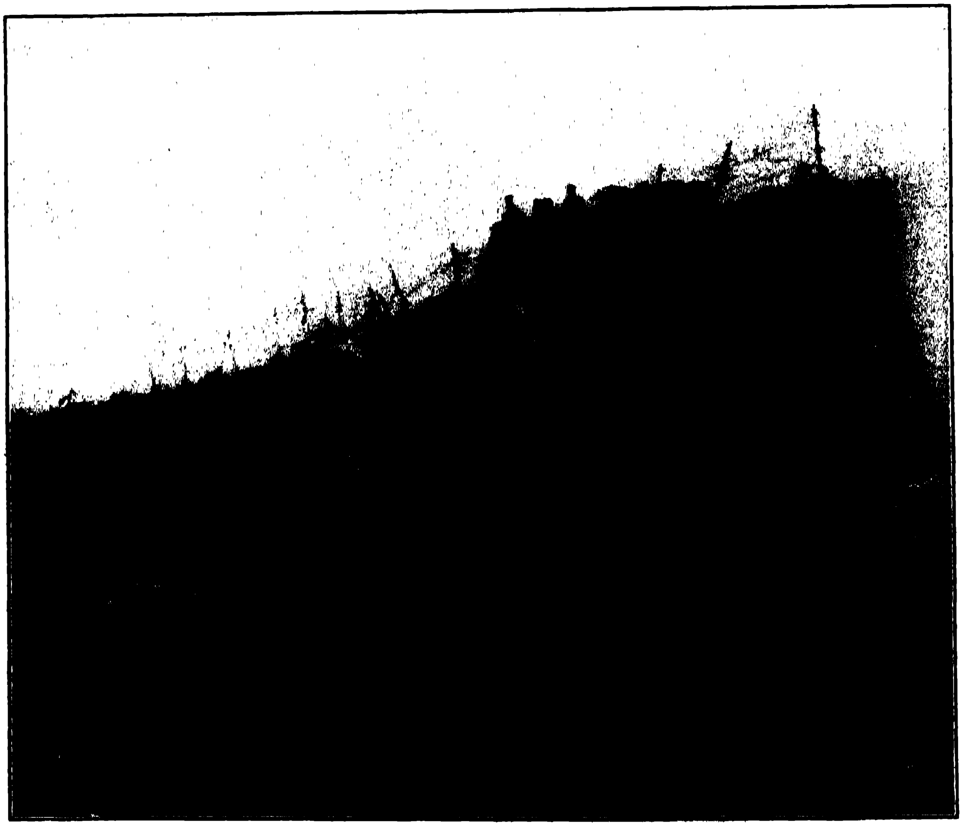
Several hundred species of plants were selected in European gardens and through the courtesy of the directors the expedition sent them in to our Washington greenhouses and propagating gardens where they will be increased for later distribution to the amateurs of horticulture in America. Acknowledgment of these courtesies will appear in print in the literature in which each various plant introduced is described officially. The standing offer which for thirty years has been operative, that of sending to any garden or other reputable institution abroad new plant material which is asked for from our own collections, may be expected to return these many courtesies shown to me by the botanists and horticulturists of the many countries visited by the expedition.

A stock of seeds of certain interesting new plants was, furthermore, carried on the yacht and distributed wherever the climatic and other conditions were right for their successful growth; so that the work of plant introduction as a result of the expedition's activities will be in no way confined to America or American territories.

The Argan Tree of Morocco

One of the interesting investigations carried out was that relating to the Argan trée of Morocco—a dry land tree

of the *Sapotaceae* which occurs in only one limited area of the world—that of Western Morocco. Here it forms great open forests covering about a million acres of territory. The extreme drouth resistance of the tree, the fact that its fruits, young branches and foliage make excellent forage for goats and cattle and that its seeds furnish a cooking oil has retained this unique slow growing tree (*Argania sideroxylon*) in the dry land agriculture of a remarkable agricultural race—that of the Berbers. The sight of herds of goats browsing in the very tops of the Argan trees, twenty feet above the ground, is one never to be forgotten by any one who has seen it.



PROFESSOR RENÉ MAIRE, AUTHORITY ON THE MOROCCAN FLORA, AND MR. DURAND, WITH ARMED GUARDS, BOTANIZING UNDER THE BLOCK HOUSES WHICH OVERLOOK THE RIFFIAN BORDER NEAR OUEZZAN, MOROCCO. THIS TERRITORY HAD NEVER BEEN BOTANIZED OVER BEFORE BY ANY EUROPEAN BOTANIST. WE FOUND SEVERAL NEW FORMS, DISTINCT FROM THE SPECIES, WHICH OCCUR IN OTHER PARTS OF THE MEDITERRANEAN BASIN. THE RARE *Narcissus elegans* WAS SECURED HERE AND SENT TO AMERICA.

Although its cultivation, like that of the Mediterranean Carob, offers little immediate prospect of commercial exploitation in Southern California, the beauty of the tree itself and its astonishing resistance to drouth, make it very desirable that it be added to the shade and landscape trees of the dry hillsides of that state. Utilization of its stony hard seeds and its foliage may be left to another generation to determine.

The Retama as a Sand Binder

Among the sand dunes which before the French occupancy of Morocco threatened to overwhelm the old town of Magador there are growing certain extremely tenacious rapidly growing legumes whose root systems have retained the sand and whose broom-like branches cut for the purpose have been used by the French forestry officials to bind the shifting sands. These Retamas (*R. Bovei* in particular) may perform the same useful purposes when grown on the troublesome sand dunes of the Pacific slopes. They are attractive when in bloom, and since their flowers exhale a delicate fragrance they may prove of not only commercial but esthetic importance in America. They are already used for forcing purposes in Southern France and one sees them on the Paris flower market.

Morocco a Plant Paradise

Morocco, which in itself proved one of the most fascinating collecting regions visited by the expedition, was made much more so by the courtesies of Professor René Maire, the authority on its flora with whom we were able to make several most interesting excursions—one in particular to the virgin botanical territory of Ouezzane (just before the recent outbreak of the Rifflans), where no European botanist had yet been.

The cork forest of Marmora with its unbelievable wealth of bulbous plants and its soil so pliable that a slender dry grass halm can be thrust into it eight or more inches with ease, would repay any bulb collector to visit. He should be there in April. Any botanist would be fascinated by the rich alluvial river bottom of the Oued Sebou (?) where the Lavateras, Borages, Calendulas and wild mustards made a show of color more remarkable than any bedding out plants in any park I have ever seen; the rock outcrops of Socrat en Nemra in whose crevices grow all sorts of rare species of legumes and bulbous plants and at whose base occurs the original wild species of *Pisum* from which the cultivated pea originated; and *Linum angustifolium*, the flax of the Swiss lake dwellers. In the shade of the giant Atlas Cedars of Azru Professor Maire discovered a few years ago that remarkable species of Cytissus (*C. Battandieri*) which resembles nothing I can imagine unless it might be a golden flowered lilac with leaves which are covered with even softer, silkier hairs than those of the famous *Leucodendron argenteum* of Table Mountain, South Africa. Thanks to its discoverer, Professor Maire, seeds of this rare and beautiful shrub have been sent to California to grow there beside the Deodars and Atlas cedars of California gardens, and where already a tiny Leucoium, which we found in the forest of Marmora, is growing and blooming.

The Canary Islands

The Barrancos of the Canary Islands furnished some interesting forage plants; *Sonchus leptocephalus*, with a strange mouse odor of which the goats are very fond and an ability to establish itself in the arid almost barren rocks; *Cytissus proliferus*, the "Tagasaste," a leguminous cultivated crop; *Psoralia bituminosa*, also leguminous, the so-called "tedera" of the goat herders who scatter its seeds wherever they go over the hillsides because of the luxuriant growth of forage which it produces in early spring; and the "Gacia" (*Cytissus stenopetalus* var. *sericea* Pitthard), which is more limited in its uses than the Tagasaste, were some of the more useful plants found of which seeds were obtained.

The volcanic island of Lanzerote is the strangest island of the archipelago. It is an almost rainless island and parts of it

THE PROBLEM OF RUBBER PRODUCTION IN WEST AFRICA SEEMS TO BE AS MUCH A PROBLEM OF LABOR AS IT IS ANYWHERE ELSE. THESE TAPPERS, WITH THEIR PAILS OF LATEX, HAVE JUST COME IN FROM THE FIRESTONE RUBBER PLANTATION IN LIBERIA. THEY REPRESENT EIGHT DISTINCT TRIBES SPEAKING EIGHT DIALECTS, YET THEY SEEM TO BE ABLE TO COLLECT THE RUBBER, THOUGH WITH HOW MUCH PROFIT TO MR. FIRESTONE REMAINS FOR HIS EXCELLENT ORGANIZATION TO DEMONSTRATE.

are covered by a deep layer of cinders which were thrown out by its "Volcan de Fuego." Delicious grapes are grown in special pits dug in the cinders which collect the dews from the low blanket of clouds which covers the island nearly every night. A true brachitic dwarf maize not over two feet high is grown in the dew wetted cinders, but it takes as long to ripen its single ear of corn as an eighteen-foot corn stalk does to ripen its ears in the Kaw Valley. What it will do in other cool foggy climates remains to be seen.

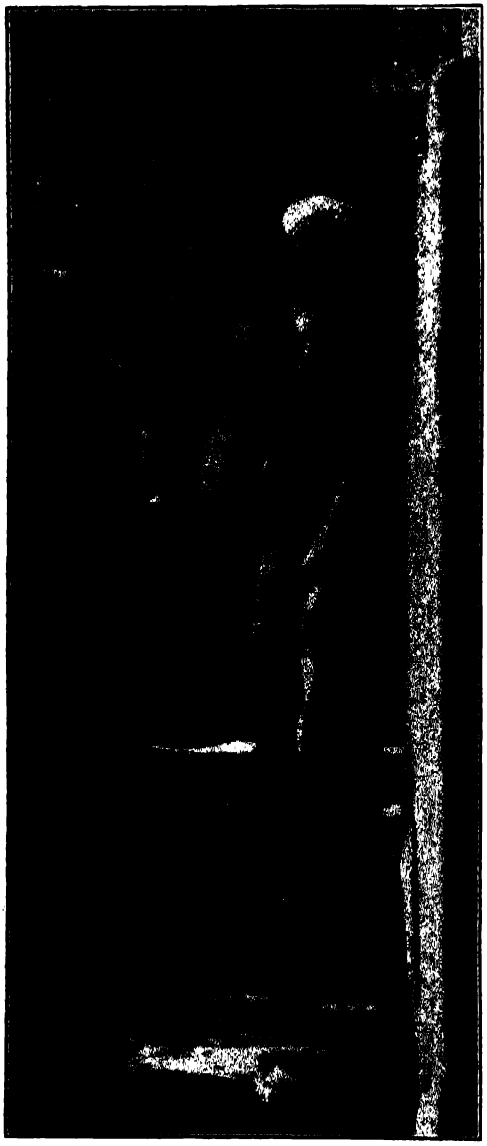
Whether the handsome Canary Island *Juniperus cedrus,* with its drooping branchlets, will be hardy anywhere on the Pacific coast or in Florida may require many trials to determine. As it is becoming rare in the Canaries it should be planted in other regions before it becomes extinct.

Some of the unique giant Aeoniums like *Aeonium tabulaeforme* with its great golden yellow inflorescences and dinner-plate-like rosette of leaves which grow on the perpendicular walls of the barrancos; the gorgeous blue *Echium pininana* with spikes twelve feet high and the handsome *Statice arborea,* to say nothing of the Giant Dragon's Blood tree, are among those plants of the Canaries which may be given a trial in California and Florida as a result of the expedition's collections.

A Tomato from the Balearic Islands

What are probably the best of the dried tomatoes on the Spanish markets are of an especially uniform variety grown on the slopes of Majorca at Banalbufar, on the remarkable terraces for which the island is noted, and dried there in special drying houses before being shipped to Spain. If this variety should prove adapted to the needs of the tomato growers of America, it may become a valuable addition to the varieties grown in this country, for its uniformity, brought about by selection, is remarkable and the fruit remains attached to the stem in the drying process—

HEAD MEN OF THE VILLAGE OF BROFUEBRU, ON THE GOLD COAST, STANDING IN A PATCH OF A SPECIES OF TALINUM WHICH HAS ALMOST OVERRUN THEIR GARDEN. THIS VEGETABLE IS ALSO MUCH USED IN CEYLON WHERE THE SINGHALESE LIKE IT IN THEIR CURRIES AND IT IS NOW BECOMING POPULAR IN FLORIDA AS A SUMMER GREEN VEGETABLE.



THE VETERAN PLANT INTRODUCER OF ALGERIA, DR. L. TRABUT, STANDING IN THE COURTYARD OF HIS RESIDENCE AT 7 RUE DES FONTAINES, MUSTAPHA, WHERE HE HAS WORKED FOR OVER THIRTY YEARS. THROUGH HIS REMARKABLE PLANT INTRODUCTION GARDEN HE HAS BROUGHT TO THE ATTENTION OF THE HORTICULTURAL WORLD A MOST UNUSUAL NUMBER OF NEW AND USEFUL PLANTS. HE HAS A PASSION FOR DOMESTICATING AND HYBRIDIZING WILD SPECIES IN WHICH HE DISCOVERS AGRICULTURAL POSSIBILITIES.

unlike many varieties which drop off when hung up by the stem.

The Slow Exchange of Cultivated Plants in the Tropics

So many centuries have elapsed since Europeans first visited the tropical regions of the western hemisphere that we are prone to think of the cultivated plants of the Oriental Tropics as having had ample time to find their way into use in the Occidental Tropics. This is a great illusion and one which arises from man's ignorance of the difficulties encountered in taking a living tropical plant half way round the world. The seeds of many tropical plants are very short lived. If dried they die and if kept moist they germinate in a few days, so that the only way to send them is as seedlings in Wardian cases. From Singapore to Panama by the fastest mail route is to-day about two months and there are few things in nature which are deadlier to tender young plants than salt spray. So that when a delicate seedling of some especially valuable Oriental plant starts on a journey towards South America it has rather poor chances as a rule of arriving alive. Every exchange of letters between the two countries takes months out of the lives of those interested in the introduction, and the few horticulturists living in the Tropics who are interested in plant introduction change their posts frequently. When this fact is taken in connection with that of the delayed correspondences, it is easy to understand why so many plants in one part of the tropical world are unknown in another. Then, too, the picture which one is apt to form of the tropical world being filled with men who are studying the uses of plants and trying to find out new ones is utterly unwarranted by the facts, for if the botanists of the whole tropical world were to gather together they would not

form a very impressive assembly, and they could easily be accommodated in the dining room of a small town hotel. Invention and research have scarcely yet touched the confines of the tropical world, even though exploitation is destroying fast the forests which harbor thousands of forms of unknown potentiality. With the opening of the highway overhead will come, let us hope, a quicker plant exchange from continent to continent.

North Sumatra

Sumatra with its ten thousand species of plants, is full of new "plant possibilities," but to get them out and over to the western world will require many years and many expeditions—and yet it is only one of the many richly forested islands which compose the Dutch East Indies.

Leguminous cover crops, new and as yet untested fruit trees, wild relatives of citrus fruits, magnificent new shade trees for tropical roadways, rapidly growing timber trees, and trees yielding gums and tannins and drugs abound in it, but as yet their value is too little known to make their introduction into our American tropics a matter of great popular interest.

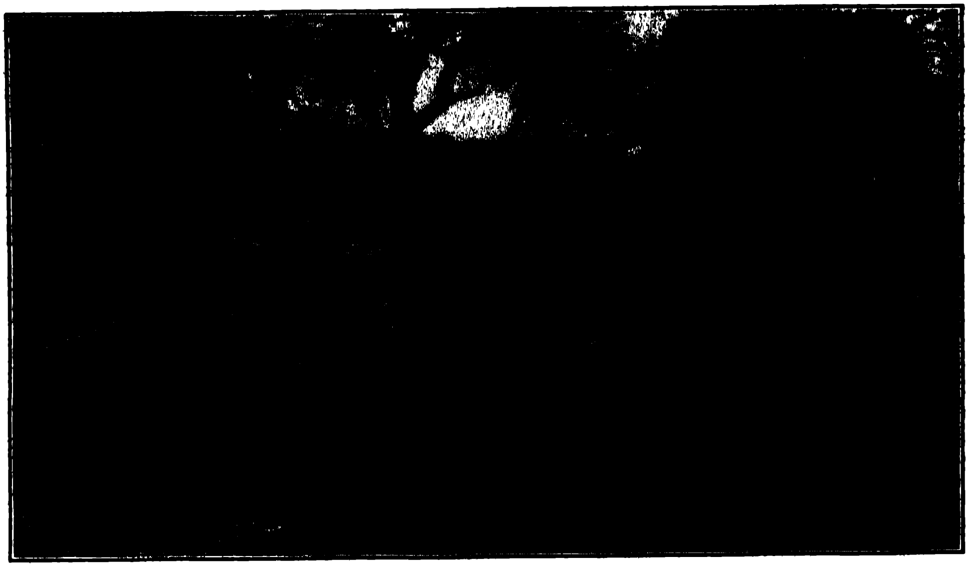
However, the Merkus pine (*Pinus Merkusii*) is an exception, for plantations of it are being started in Atjeh and from it Mr. Brandts Buys has obtained a superior quality of turpentine by certain improved methods of tapping. This might develop into a plantation industry of such dimensions as to command the attention of American turpentine manufacturers. Its cultivation on a gigantic scale in the mountainous regions of the Tropics might even become the chief source of turpentine in the next century.

What man may require to-morrow to cater to his new tastes and contribute to his new playthings we have no way of surmising, but the example of rubber and gutta percha, cocoa and sugar ought to make us careful with our predictions, for almost every change in the world of invention is reflected in the world of raw products and the tropical world is that world.

DR. WILLIAM MORTON WHEELER IN A MOMENT OF TRIUMPH. HE HAD JUST DISCOVERED THE REMARKABLE DIPTEROUS INSECT, VERMILEO, WHICH BUILDS CRATERS LIKE THOSE OF THE ORDINARY ANT LION IN THE DUST COVERING THE FLOOR OF A HOLE IN THE ROCKS. MAJORCA, BALEARIC ISLANDS.

The Bamboos of Java

We are accustomed to associate bamboos with China and Japan, where large groves of at least three species do occur



IT IS RARE TO FIND A TREE WHICH IS CONFINED TO SO SMALL A REGION AS THIS ARGAN (*Argania sideroxylon*), WHICH OCCURS ONLY IN MOROCCO. BACK OF MOGADOR THE ARGANS ARE SCATTERED OVER THE DRY PLAINS LIKE ORCHARD TREES AND, ALTHOUGH THEIR FRUITS ARE HORRIBLY ACRID AND THEIR BRANCHES COVERED WITH SHORT SPINES, THE COUNTRY IS SO DRY THAT THEIR FOLIAGE AND FRUITS ARE OFTEN THE ONLY FOOD AVAILABLE FOR GOATS AND CATTLE. THE BERBER WOMEN MAKE A TABLE OIL FROM THE SEEDS AFTER THEY HAVE PASSED THROUGH THE INTESTINES OF THE ANIMALS.

and where a great use is made of them, but after my third visit to Java I am convinced that the Javanese rather than the Chinese or Japanese are the greatest employers of bamboo in the world. In China and Japan one sees innumerable field and household utensils and furniture made from bamboo, in Java as a general rule the houses themselves are made substantially of bamboo. The walls, the floor joists, the rafters, the flooring and often the roofs themselves are made of bamboo. I imagine there are in the neighborhood of 7,000,000 bamboo houses in Java alone, housing a population of 35,000,000. The Javanese live in bamboo houses and this can not be said of the Chinese or Japanese. Notwithstanding this great use of bamboo by the Javanese, one sees few large groves of bamboo in Java. The explanation lies in the fact that each householder grows his own small clump in his own yard and that in place of growing a species of the genus *Phyllostachys*, which has creeping or running rhizomes, they cultivate three caespitose species which are clump but not grove-forming and belong to the genera *Gigantochloa* and *Dendrocalamus*. The most important species are *G. Apus*, the "Tali" bamboo, a non-edible species of large size, the culms of which are used for making bridges, rafters, etc., and when split, for tying material; *G. Verticillata* "Andong," used extensively for making the mats or "Bilikken," which form 99 per cent. of the walls of the Javanese houses; *G. Asper*, Backer, the "Betong" bamboo, which is the largest of the Javanese species and that of which the young shoots are most used for food.

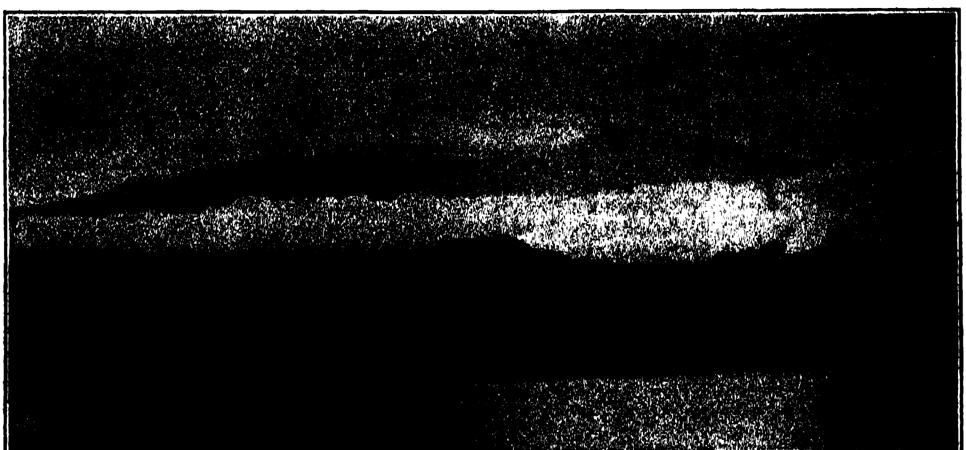
These bamboos strike me as distinctly cultivated plants, which have been in

culture in Java for many centuries. They have culms that rise perfectly straight from their rhizomes and without a curve attain a height of twenty to twenty-five meters, and unlike so many tropical bamboos have no short spiny branches near the ground. As compared with any other species of bamboo I have ever seen they appear to be far the most useful of all for tropical house building. Their introduction and popularization in the tropics of the Western Hemisphere and West Africa should long ago have been carried out. They split easily; their thin strips make remarkable tying material and they lend themselves to a vast variety of uses and should be grown in every native dooryard in the Tropics.

I believe their use would be likely to eliminate many of the other species with which I have become familiar and whose introduction into the Western Tropics so far has been attended with only a modicum of success. Even that giant bamboo, *Dendrocalamus gigantea*, far famed through the splendid hundred-foot-high clumps in the Peradeniya Gardens in Ceylon, is a distinctly less useful form. In Ceylon, in fact, little use is made of bamboo as compared with the extensive use made of it in Java.

Relatives of the Breadfruit

When Lieutenant Bligh, of the famous ship *Bounty*, brought the breadfruit to the West Indies from the South Sea Islands, I doubt if he would have even looked at its relative, the Jack-fruit tree. Yet to-day in Ceylon it is this Jack-fruit and not the famous breadfruit which has come to form the second most important food plant grown in that tropical island. The "Honey Jack," which produces its enormous twenty-five pound fruits borne on the tree trunk, deserves a special study by tropical agriculturists, for not only do its large seeds form a nutritious concentrated protein food, but the golden yellow arillus surrounding the seeds is so delicate and sweet that it forms one of the most sought-after delicacies of the Singhalese menu. The unripe fruit also forms an



CAMEROON MOUNTAIN WHICH RISES OVER THIRTEEN THOUSAND FEET ABOVE SEA-LEVEL AND IS THE HIGHEST ELEVATION ON THE WEST COAST OF AFRICA. BELOW ARE SHOWN THE OIL MILLS AND OFFICES OF THE GERMAN COMPANY WHICH IS ACTIVELY DEVELOPING ITS PLANTATIONS AFTER THE FORCED INACTIVITY RESULTING FROM THE WAR. THESE PLANTATIONS ARE PROSPERING UNDER THE BRITISH MANDATE. THE WEALTH OF PLANT FORMS TO BE SEEN IN THE JUNGLES OF THE CAMEROON ARE SURPASSED ONLY BY THOSE OF THE RICHER MALAYAN REGION.

GATHERING SEEDS OF THE WEST AFRICAN OIL PALM (*Elaeis guineensis*) FROM AN OLD SPECIMEN IN A CACAO ESTATE IN THE CAMEROON. THE OIL PALM OF WEST AFRICA IS THE MOST IMPORTANT FOOD-PRODUCING PLANT OF THAT REGION AND ITS OIL IS ONE OF THE MOST VALUABLE OF THE VEGETABLE OILS. THIS PALM IS DESTINED TO PLAY A MOST IMPORTANT RÔLE IN THE DEVELOPMENT OF THE TROPICS.

important constituent of their curry. The Honey Jack is a special variety, far superior to common seedlings.

Furthermore, as a tropical timber tree it ranks so high that the Ceylon Forestry Department is urging its planting on a large scale. It has soft easily workable wood containing a brilliant yellow dye.

The whole Genus Artocarpus, comprising sixty species, deserves to be more widely known, for it contains besides the breadfruit and the Jack-fruit trees, *A. falcatum, A. Champeden, A. lakucha, A. elastica, A. gomeziana, A. rigida, A. polyphemia* and *A. odoratissima,* all superb trees with edible fruits which as yet have been in no way selected for quality. *A. Nobilis* and *A. lancaefolia* are two superb species not having edible fruit, but useful as avenue or shade trees in tropical gardens. In South Florida several species have already shown themselves remarkably well adapted to the limestone soils there.

Casuarinas, the So-called She Oaks or Australian Pines

The so-called She oak or Australian pine, *Casuarinas equisaetifolia,* has played a great rôle in most tropical lowlands near the sea. It is to be seen on almost any seashore from Florida to Celebes, but there are rarer and more attractive species than the common one and their introduction deserves consideration. Seeds of *C. Sumatrana, C. montana, C. suberosa* and *C. Rumphiana* were secured and sent in by the expedition. The fact that hybrids between certain of these species have been found in Algiers makes it likely that there could be produced by breeding forms which would grow even more rapidly than the phenominally rapid growing species, *C. equisaetifolia,* and have a much more attractive form. The success of Dr. Trabut's hybrid Eucalyptus in Algiers (*E. Trabuti*) might be paralleled by that of some hybrid casuarina. The wood of this rapidly growing tree known as Beef Wood in Australia has not yet come into its own as a timber, although it makes exceptionally durable tool

handles. As a fire wood it is distinctly valuable.

Terrestrial Orchids for Tropical Border Gardens

To find a terrestrial orchid of easy culture which might be depended upon to beautify the private gardens of our extreme South has always been a special desire of mine and while in Ceylon and Singapore my attention was particularly attracted by the two species of Arundina, *A. Chinensis* and *A. Bambusaefolia,* whose grass-like stems rising several feet in the air bear small but very beautiful Cattleya-like flowers that are very attractive indeed.

Dr. Trabut called my attention to *Orchis robertiana,* which grows commonly in Algiers and which from his experience is one of the easiest of all to be grown in borders. We saw *Orchis papilionacea,* a terrestrial species of real beauty, blooming back of Amismiz, in the Atlas Mountains of Morocco. It was growing wild in the dry soil which baked as hard as brick and it seemed as though it should grow easily in the gardens of California.

In the pine forest (*Pinus Merkusi*) of North Sumatra, I saw growing for the first time the glorious ground orchid five feet high, *Phaius tankervilliae,* which the literature reports as one of the first plants to be imported from the Dutch East Indies into European greenhouses. Its culture might add great beauty to Florida landscapes.

As we rode from Accra to Winneba last February through the low Savannah which fringes the Gold Coast we saw patches of that superb ground orchid, *Lissochilus Heudelottii,* which grows to four and a half feet in height and has purple-lipped flowers as beautiful as small cattleyas. Its tubers resemble new potatoes and are produced in short chains three or so in a chain. Since the Accra Plain is subjected to extreme summer drouths it would appear quite possible to acclimatize such a species as this in the warmer parts of California and South Florida.

THE WONDERFUL PALMYRA PALM (*Borassus flabellifer*), WHICH SURPASSES THE CABBAGE PALMETTO OF FLORIDA IN STATELINESS AND WHICH WILL PROBABLY GROW AS WELL IN SOUTH FLORIDA AS IT DOES IN THE JAFFNA REGION OF NORTHERN CEYLON. GROVES OF IT ARE AS BEAUTIFUL AS GROVES OF THE DATE PALM IN EGYPT.

But the handsomest of all the terrestrial orchids which I have ever seen was a species blooming in the conservatory

Artocarpus champenden, ONE OF THE LITTLE-KNOWN RELATIVES OF THE BREADFRUIT AND JACK-FRUIT TREES, WHICH IS CULTIVATED IN THE SINGAPORE REGION AND SOLD ON THE MARKETS THERE, BUT WHICH HAS NEVER BEEN GROWN SO FAR AS I KNOW IN THE WESTERN HEMISPHERE.

of the Botanic Garden in Munich, which Professor Goebel showed me last June (*Sobralia macrantha*), from the Indo-Malayan region. Its immense cattleya—like deep pink flowers, although wilting too quickly to make it useful for cut flower purposes, might make it a species of the greatest interest for out-door culture in our extreme South and in tropical regions generally.

Citrus Fruits and Citrus Regions

The following very brief notes on citrus regions and citrus fruits have been collected during the past three years of travel. They may prove of interest to citrus growers and are represented by photographs in my albums of travel.

The commercial orange culture of Bou Farik in Algiers is that from which the Paris market gets part of its supply of oranges. It produces exceptionally fine-flavored dark-colored tangerines and sweet oranges. Dr. Trabut's new Bigaradier "orange à confiture" with a thick rind, making it valuable for marmalade purposes; and his Limoncello, seedless lime from Palermo, also worthy of our study, is a new possibility. The beautiful oranges of the region about Port Say, Northern Morocco, were disappointing so far as flavor was concerned. The spotless orange trees in an isolated Arab Patio in Ouezzan, where no European disease had yet penetrated, was a striking illustration of the fact that plants can be protected from disease by isolation.

The famous oranges of the little village of Telde in the Island of Grand Canary—so noted that a special tree was kept loaded with its beautiful fruits for the Duke and Duchess of York to see, I found particularly attractive with no "rag," kidgloved, beautiful skin, very juicy and not too sweet. These Telde oranges I am told bring a fancy price on the London market.

A to me extremely interesting and seemingly disease-resistant relative of the orange was *Atalantia missionis*, which I saw growing in the Regent's Park in Jaffna, Ceylon, and it ought certainly to be tested as a stock for citrus fruits. Because of its superb ornamental appearance alone it is worth introducing. Its foliage was spotless and scaleless and hundreds of seedlings were growing under the tree.

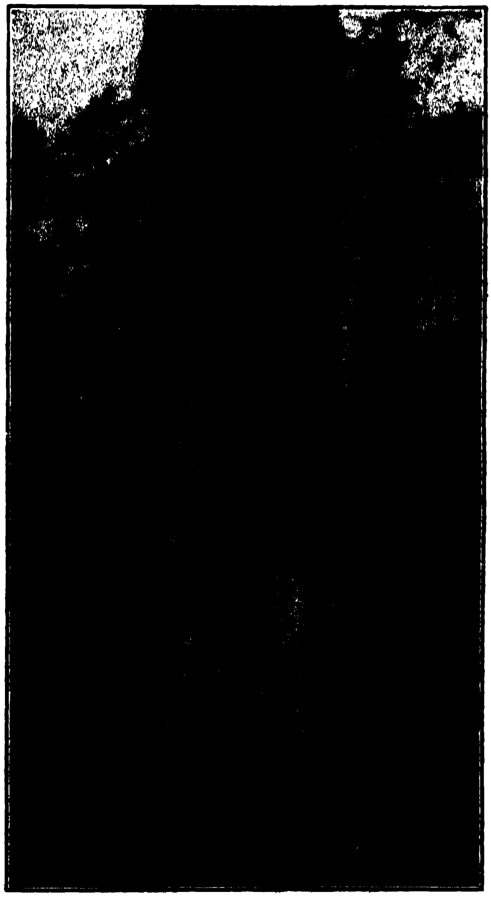
To stumble upon a large wild citrus tree, as Mr. Dorsett did, in the very heart of the jungles of Atcheen, and

later find fruit of what looks to be the same species for sale in a mountain village market near Takengon, N. Sumatra, was an exciting experience, even though the fruit was too aromatic to be good to eat and was only used by the natives for washing their hair. I judge it to be a wild relative of our grape fruit. Seedlings from a fruit sent to Washington are now growing there.

To tear open a Javanese pink-fleshed shaddock is a delightful experience and sooner or later our American tables should be supplied with the best of these fine Javanese shaddocks, since living seedlings of the best varieties are now growing in America. The deep pink color of the fruit flesh would add a very attractive touch to our fruit salads.

Mr. Ochse, of the Department of Agriculture in Buitenzorg, Java, gave us seeds of what he is pleased to call the "Japanese citron," which he discovered in the native Kampongs or villages of Java and which has proven a remarkable stock for the very wet lands of Western Java. This may prove of value as a stock for Panama and Honduras. The so-called Kaffir Lime (*Citrus Acida*) of North Sumatra which is used as a head wash by the natives may also prove valuable as a citrus stock somewhere.

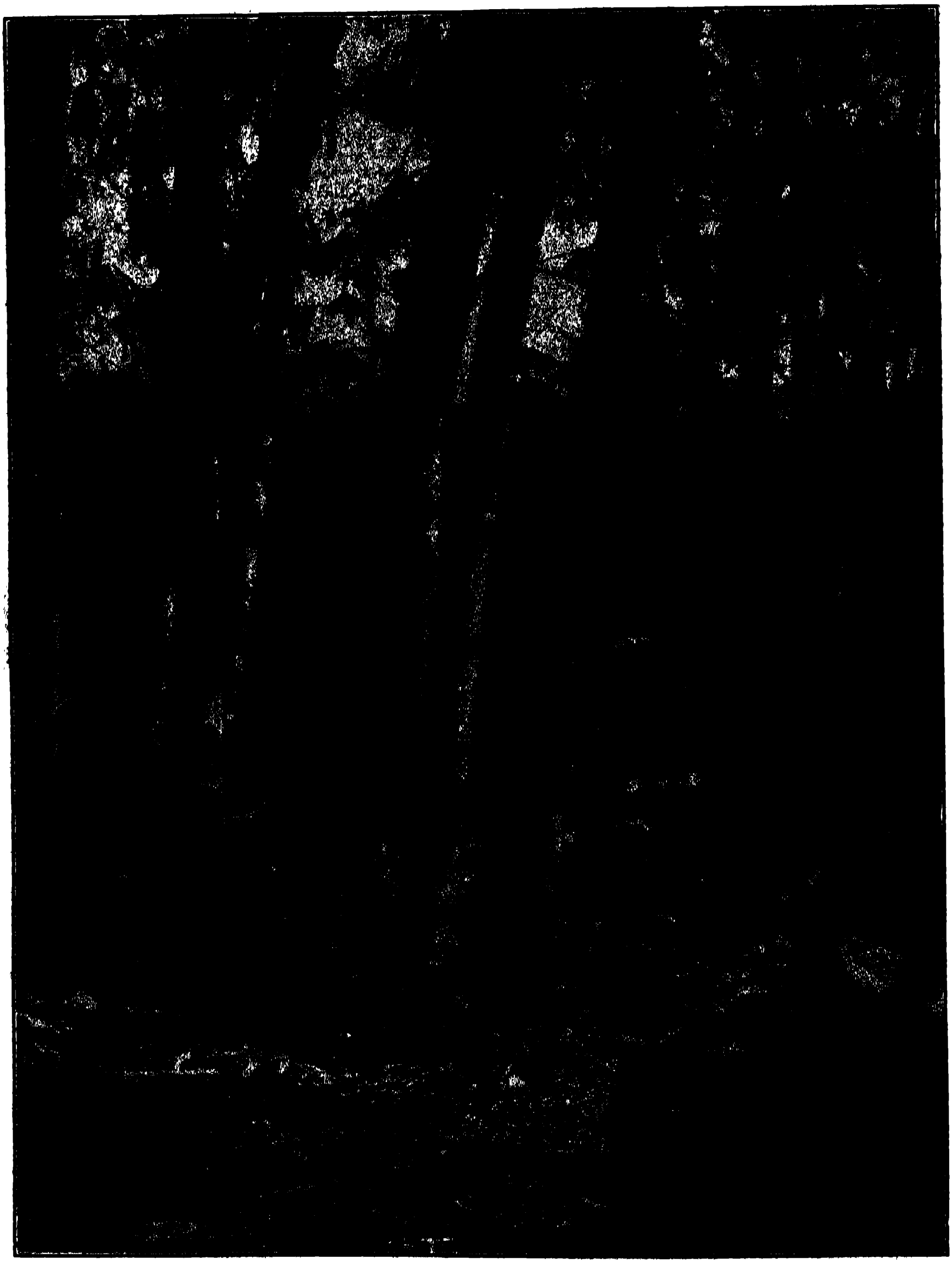
But perhaps the most unexpected of the citrus relatives seen by the expedition is the tree furnishing the so-called "Curry Leaf" of Ceylon (*Murraya Koeningii*), of which one finds fresh leafy twigs for sale in every large market in the island. The use of the fresh leaves of this close relative of the orange Jasmin (*Murraya exotica*) seems to be almost universal in Ceylon and to it may be ascribed the characteristic oriental flavor of the Ceylon curry. Its culture in South Florida should be easy and it ought to enter the list of our flavoring vegetables. We use the laurel leaf of the Mediterranean region; why not the curry leaf of Ceylon? One sees beautiful oranges in March on the Malaga market in Southeastern Spain, but none that appeared to me unusual enough to deserve to be experimented with. They represent the Valencia-grown varieties.



—*Photo by J. H. Dorsett*

DR. BRANDTS BUYS HAS DEVISED THIS METHOD OF GATHERING THE TURPENTINE OF THE TROPICAL PINE (*Pinus merkusii*) IN NORTHERN SUMATRA. HE BELIEVES THE NEW TECHNIQUE IS A GREAT IMPROVEMENT ON METHODS USED IN EUROPE AND AMERICA AND EXPECTS IT TO GIVE THIS TROPICAL TURPENTINE-BEARING PINE GREAT POSSIBILITIES AS A PLANTATION CROP.

Of orange culture in the West African colonies the best fruits I saw were among the Fulla tribes of the Fouta Djallon Mountains of French Guinea.



TWO OF THE REMARKABLE CULTIVATED BAMBOOS OF JAVA, THE "BETONG" AND THE "TALI" (*Dendrocalamus asper* BACKER, AND *Gigantochloa apus* KURZ). OUT OF THE CHARACTERISTIC TIMBER OF THESE TWO BAMBOOS MORE THAN THIRTY MILLION PEOPLE BUILD THEIR HOUSES IN THE ISLAND OF JAVA. THEY SHOULD BE PLANTED WHEREVER THEY CAN BE GROWN IN THE TROPICS OF THE WESTERN HEMISPHERE.

The juiciness and high flavor of the fruits sold to me (fifteen for a French franc, four cents) by natives of this tribe make it seem quite possible that in these remarkable mountains a citrus culture may be developed which will reach Europe with its products. I was not favorably impressed by any of the citrus fruits I saw in any of the other West African colonies and upon what grounds the hope of a great citrus culture in any of them is based, I do not understand. I believe citrus culture will for a long time to come be largely a matter of the control of the diseases which molest the trees.

Mango Varieties and Stock Species

I was much disappointed not to discover any mango varieties in Ceylon, Java, Sumatra, Singapore, Penang or West Africa which are particularly worthy of the attention of Florida growers. It was not the mango season, it is true, but I studied the colored drawings of the varieties grown in Ceylon and Java and interviewed every one who would be likely to know about mangos and nowhere could I get trace of a variety so showy as the Florida "Hayden." I was unable, however, to visit British India or Burma, where the best of our collection of mangos now in Florida came from. Perhaps there are forms in the gardens there better than those we have already imported and are growing in Florida. In the highlands of North Sumatra we saw a single giant mango tree of unbelievable size but poor fruit. It stood on the shores of Lake Tawar and remains in my memory as one of the most beautiful trees of any species which I have ever seen. In East Java I studied the newly started mango collections of Dr. Ochse and saw the excellent watercolor drawings of Mr. E. de Vries, but found no single variety as showy as the Hayden. All mangos there are propagated by inarching. That some of the Javanese varieties will do better in wet regions than our Florida varieties have done, I am prepared to believe and that the stock mangos "Nanas" and "Kopior" adapted to alkaline soils may prove extremely valuable in American mango culture, I think quite probable.

In Egypt on the islands in the Nile a mango industry has grown up since I was first there in 1902. This seems to be built upon the basis of a single small fiberless variety of good quality, trees of which I saw in Prince Mohamet Ali's garden in Cairo.

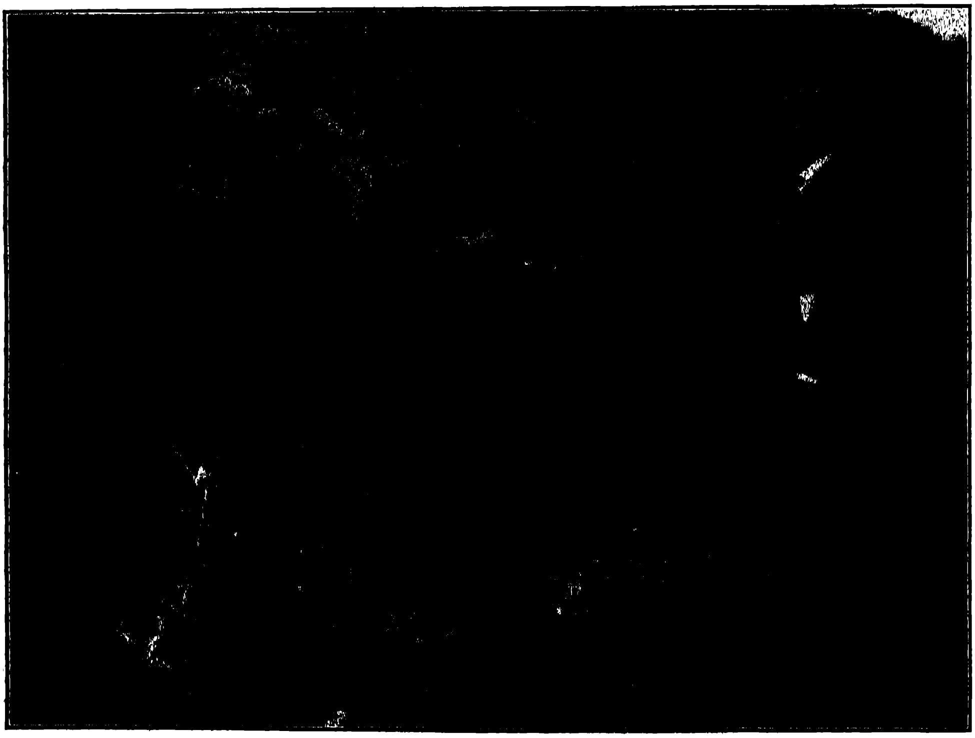
Nowhere have I ever seen such mango *avenues* as those at Konakry in French Guinea. For miles these glorious avenues of mango trees loaded with their young fruits stretched away from the town into the country. The streets were wonderfully shaded by these trees which had been planted by the noted governor of the colony, Governor Ballay, to whose memory they form a fitting monument. Why many other places have not used the mango as a shade tree I find it hard to understand. Fear of the fruit falling on the roadway appears to be an ungrounded objection to it. South Florida should follow Konakry's example and plant an avenue of mango trees a mile long. The mango fruits from these seedling trees are fibrous but have a pink blush and are of good flavor—better than our "turpentines" it seemed to me. The French have a few grafted forms but none of outstanding quality. Why nowhere in West Africa the fiberless East Indian mangos are grown I can not comprehend.

The seeds of two relatives of the mango, *Mangifera foetida* and *Mangifera odorata,* which we bought on the Singapore markets, may, because of their rapid growth, be useful as a stock for the mango itself.

The Rubus Species of the High Altitudes in the Tropics

With the gathering of European residents in the higher altitudes of the Tropics has come into existence as interesting new problem—that of supplying them with raspberries. The number of remarkable species of Rubus which one sees in the mountain regions of Ceylon, Sumatra, Java and Africa, not to mention the enormous fruited forms of Colombia and the Hawaiian Islands, would seem to hold out to the breeder a fascinating possibility in view of the successes which have attended the improvement of the genus by breeding and selection in temperate regions.

The expedition collected over thirty species of Rubus from the mountains of the Oriental Tropics, but until some plant breeder establishes himself in the mountains of the tropics little will come, I presume, from their cultivation.



WILD PLANT OF *Nicotiana glauca* GROWING NEAR TELDE, GRAND CANARY. DR. H. H. MCKINNEY, WHO IS SHOWN IN THE PHOTOGRAPH, DISCOVERED THREE TYPES OF MOSAIC SYMPTOMS ON THIS PLANT, A DARK GREEN, A LIGHT GREEN AND A YELLOW TYPE, THE LIGHT GREEN BEING THE MOST PREVALENT AND APPARENTLY IDENTICAL WITH THE MOSAIC FOUND ON TOBACCO IN THE UNITED STATES. HE ISOLATED THE YELLOW TYPE FROM THE LIGHT GREEN TYPE BY MEANS OF HIS SPECIAL CENTRIFUGAL APPARATUS.

Relatives of the Banana

Although the literature led me to hope that the expedition might find many species of Musa related to the banana only two were actually secured worthy of note. *Musa Glauca,* which was given me by M. Loerzing, the remarkable director of the plant garden at Sibolangit in North Sumatra and a wild undetermined dark-stemmed slender form with small seedy fruits from the

jungles near Takengon, Sumatra. *Musa Glauca* with its large glaucous trunk, which is swollen at the base, makes a most attractive ornamental for garden decoration and the wild form which I found near Takengon may have value for breeding purposes.

Of the numerous African species I was able to find no material during the short stays made by the expedition on the West Coast.

Drug and Poison Producing Plants

One of the famous arrow poisons of West Africa is produced by the natives from the seeds of *Strophanthus sarmentosus,* which is a handsome flowered liana growing over the tops of tall forest trees pretty much throughout West Africa. Strophanthin is one of the most powerful heart poisons known and is secured from several species of the genus, but so far as I know none of these species has been cultivated. Ordinarily as one sees the vine in bloom it does not strike one as so particularly beautiful, for only a comparatively few flowers are produced at a time, but as we saw it back of Chief Oumarous' Compound at Dalaba in the Fouta Djallon Mountains of French Guinea, where it had been given some care by the chief who knew well of its poisonous character, it appeared as a most attractive flowering vine with its large cream white flowers, each with long tapering pennant shaped petals, with a purple base. If for no other reason than that of its beauty, it deserves to be cultivated in tropical gardens throughout the world. Furthermore the value of its seeds as a source of strophanthin should not be overlooked in its culture. Should it come into cultivation, as the result of the seeds sent in by the expedition, the credit for its introduction ought to go to Dr. Dalziel, who for years has studied its occurrence in Nigeria and was the first to describe the process by which the natives of Nigeria prepare their arrow poison from its seeds.

I saw a specimen of its giant relative in Java, *Str. Gratus,* but no seed was ripe at the time of our visit.

The Zulu arrow poison is made from the bark of *Acokanthera venenata.* I found that its near relative, *A. spectabilis,* is being used as an ornamental tree in the gardens of the Canary Islands. Whether or not it contains the same poison I do not know, but the tree deserves to be widely grown because of its handsome foliage and fragrant flowers.

The "Bassa" of Lagos (*Tephrosia Vogelii*) undoubtedly contains a poison of some kind, for its leaves pounded up and thrown into a stream, which has been dammed for the purpose, kills fish in a few minutes and gives to the skin of the natives who wade in after the fish a "dead" feeling. Its general use as a cure for mange in dogs is attested by competent observers. Being a leguminous shrub capable of easy cultivation, its properties ought to be thoroughly investigated.

Picralima Klainiana, the fruits of which are used as a remedy for fever on the Gold Coast, probably contains an alkaloid. It is as handsome a shade tree as any I ever saw and deserves to be grown in tropical gardens.

New or Rare Tropical Fruits

Twenty-five species of fruiting trees or shrubs were selected and seed of them sent to America from the various regions visited by the expedition. I think they are nearly all new or rare in the Western Hemisphere. These include the remarkable Keppel Tree, favorite fruit of the Sultan's Harem in Djokjakarta, Java (*Stelecocarpus burahol*); the "Honey" variety of Jack-fruit already mentioned; an astonishing variety of coconut called the "Nawas," even the husk of which is crisp and sweet like a

THE ARCHITECTURE OF THE BATTAK VILLAGES OF SUMATRA IS DETERMINED BY THE MATERIALS AVAILABLE, AND THE PICTURESQUE AND CHARMING RESULTS PRODUCED BY THESE PRIMITIVE PEOPLE, WHO WERE CANNIBALS ONLY A GENERATION AGO, ARE THE DELIGHT OF THE TRAVELERS. MRS. FAIRCHILD AND MR. DORSETT ARE HERE SHOWN INSPECTING THE BAMBOO FRAMEWORK OF A COMMUNAL HOUSE NEAR KABANDJAHE, SUMATRA.

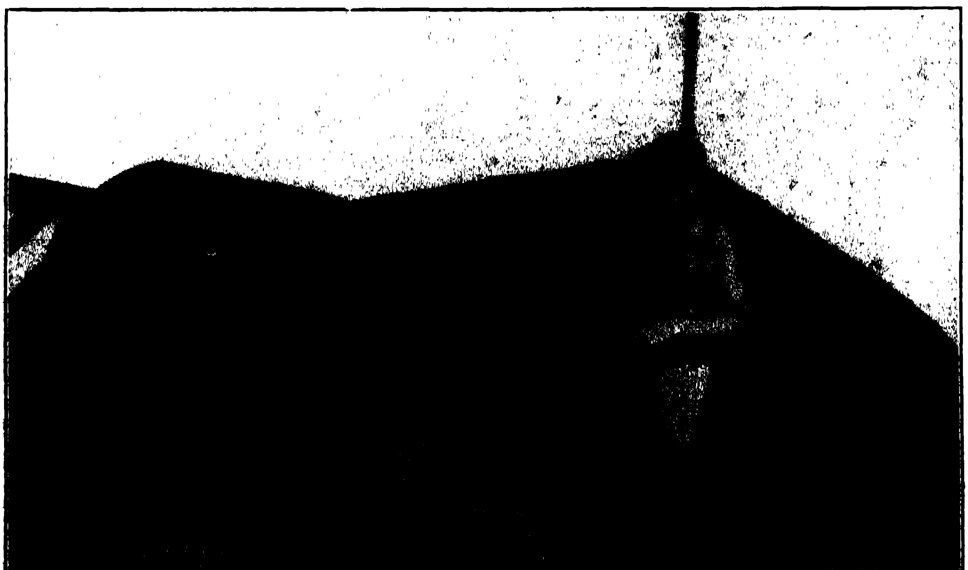
turnip; a superior Ceylon variety of the Bael Fruit (*Aegle marmelos*), which for generations has been used as a breakfast fruit by the Kings of Kandy, and which deserves to be thoroughly exploited as a fruit tree in South Florida; the "Ceylon Olive," *Elaeocarpus serratus*, which produces a palatable fruit for stewing and pickling purposes; the Lovi Lovi Tree (*Flacourtia inermis*) with its enormous crops of brilliant red acid fruits suitable for preserves; *Mimusops elengi*, a small fruit of the *Sapotaceae*, reminding one somewhat of the Sapodilla; the Miraculous Fruit (*Synsepalum dulcificum*) with fruits which make even the sourest lemon taste sweet for hours after eating it; three species of tropical Ficus with sweet, edible fruits as yet uncultivated and producing such masses of fruits that they must prove good bird food trees even if man does not utilize them; three species of the genus Dialium, called the Velvet Tamarind, whose remarkable jet black velvet fruits have an agreeable sweet acid flavor about them which will make them favorites at least among the children; the Baobab (*Adansonia digitata*) with its immense pods containing seeds covered with a chalk white arillus that resembles cream of tartar in flavor; *Balanites Egyptiaca*, the "desert date" of Senegal, a favorite of the natives of Fashoda, which, did it not have a curious bitter flavor about it, would be an excellent fruit for the Southwestern deserts of America; *Carpodinus dulcis* and *Alchornea cordata*, the "Christmas bush," two edible fruited species of shrub as yet unknown in the Western Hemisphere, I imagine, and too little known by Europeans to judge of their quality; together with two as yet undetermined new fruits which we found in Sierra Leone and the Gold Coast, re-

spectively. These make up the list of the outstanding fruit, tree and shrub introductions made as a result of the expedition. Years hence some at least will, I trust, have found a permanent home somewhere in America.

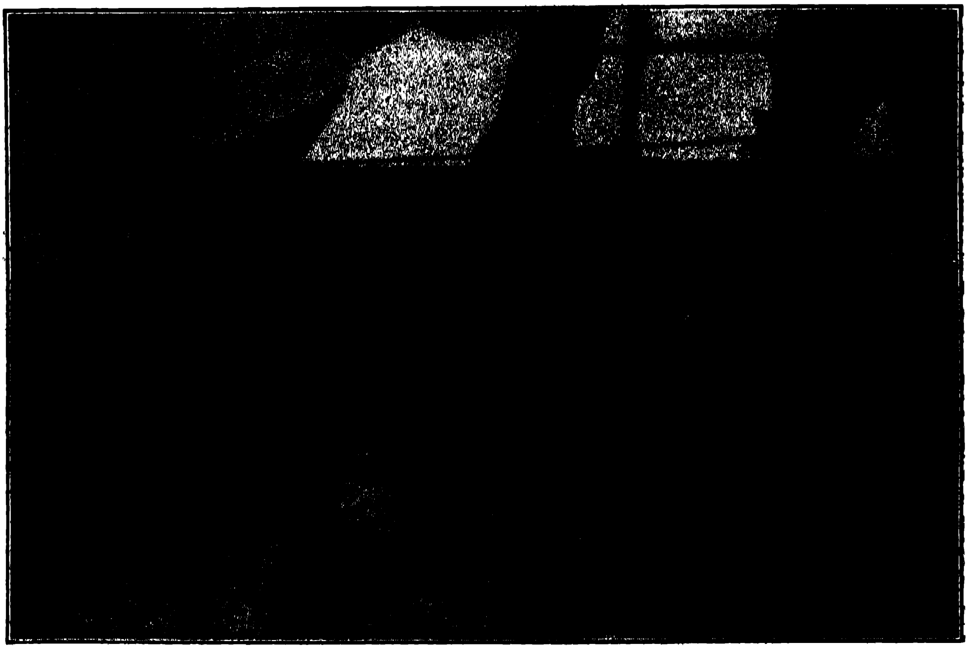
Palms

There are over 1,200 species of palm known and any expedition which would undertake to get living specimens of them together for some tropical arboretum would be undertaking a work of many years. I doubt if in any one spot in the world to-day two hundred species of living palms are to be found.

The seeds of palms are difficult to ship, which accounts for the fact that so few of the remarkable East Indian species are growing to-day in the Western Hemisphere. By removing all fermentable fruit pulp from palm seeds and replacing it with a layer of wax paper and then packing in very slightly moist finely pulverized peat we were able to land a fair proportion of our palm seed collection in Washington alive. The more interesting species included the Palmyra Palm of Northern Ceylon, *Borassus flabellifer*, and its related species, *B. ethiopum*, from the Gambia region of West Africa, both destined I trust to change the landscapes of South Florida. The *"Diwakawaka"* and *"Lisombe"* varieties of the West African Oil Palm, *Elaeis guiennense*, the two varieties from which, according to Yampowsky, the largest yields of palm oil may be expected if they can be established by selection; the famous branching Dum Palm of the Sudan, *Hyphaene thebiaca*, a landscape tree of great elegance; three varieties of the Betel Palm, *Areca catechu*, from Ceylon, where the habit



UNLESS ONE HAS TRIED TO TRANSPORT WARDIAN CASES THROUGH THE INDIAN OCEAN DURING THE SOUTHWEST MONSOON ONE HAS ONLY A FAINT IDEA OF THE DIFFICULTIES WHICH PLANTS HAVE TO ENCOUNTER WHEN STORED ON THE POOP DECK OF SOME PASSENGER STEAMER BOUND FOR NEW YORK. COVERING AND UNCOVERING THE CASES KEEPS THE SPRAY OFF OF THEM AND TO SHADE THEM FROM THE TERRIFIC TROPICAL SUN IS NOT SO EASY AS IT MIGHT APPEAR. GRAHAM TAKING OFF THE TARPAULIN ON A CLOUDY DAY.



—*Photo by H. H. McKinney*

DR. MCKINNEY GREW HIS OWN TOBACCO PLANTS IN SOIL FROM HIS OWN EXPERIMENTAL PLOTS AT ARLINGTON, VA., AND IN THIS WAY WAS ABLE TO BRING BACK WITH HIM MOST VALUABLE MOSAIC MATERIAL BY INOCULATING HEALTHY TOBACCO PLANTS WITH VIRUS OBTAINED FROM WILD PLANTS COLLECTED ON THE BARRANCOS OF THE CANARIES AND IN THE JUNGLES OF WEST AFRICA. THE SOIL WHICH HE BROUGHT IN ON HIS PLANTS WAS THE IDENTICAL SOIL WHICH HE TOOK OUT WITH HIM. THE PHOTOGRAPH SHOWS THE INGENIOUS WAY IN WHICH HE HELD THE PLANTS IN POSITION ON THE DECK OF THE YACHT.

of chewing the betel-nut seems to be on the increase in strong contrast with Java, where it appears to be on the wane; the unique Rattan Palm (*Pigafettia elata*) from the Moluccas, a most amazingly rapid grower, attaining a height of sixty feet in less than seven years—a palm deserving of much more attention for avenue purposes than it has hitherto received.

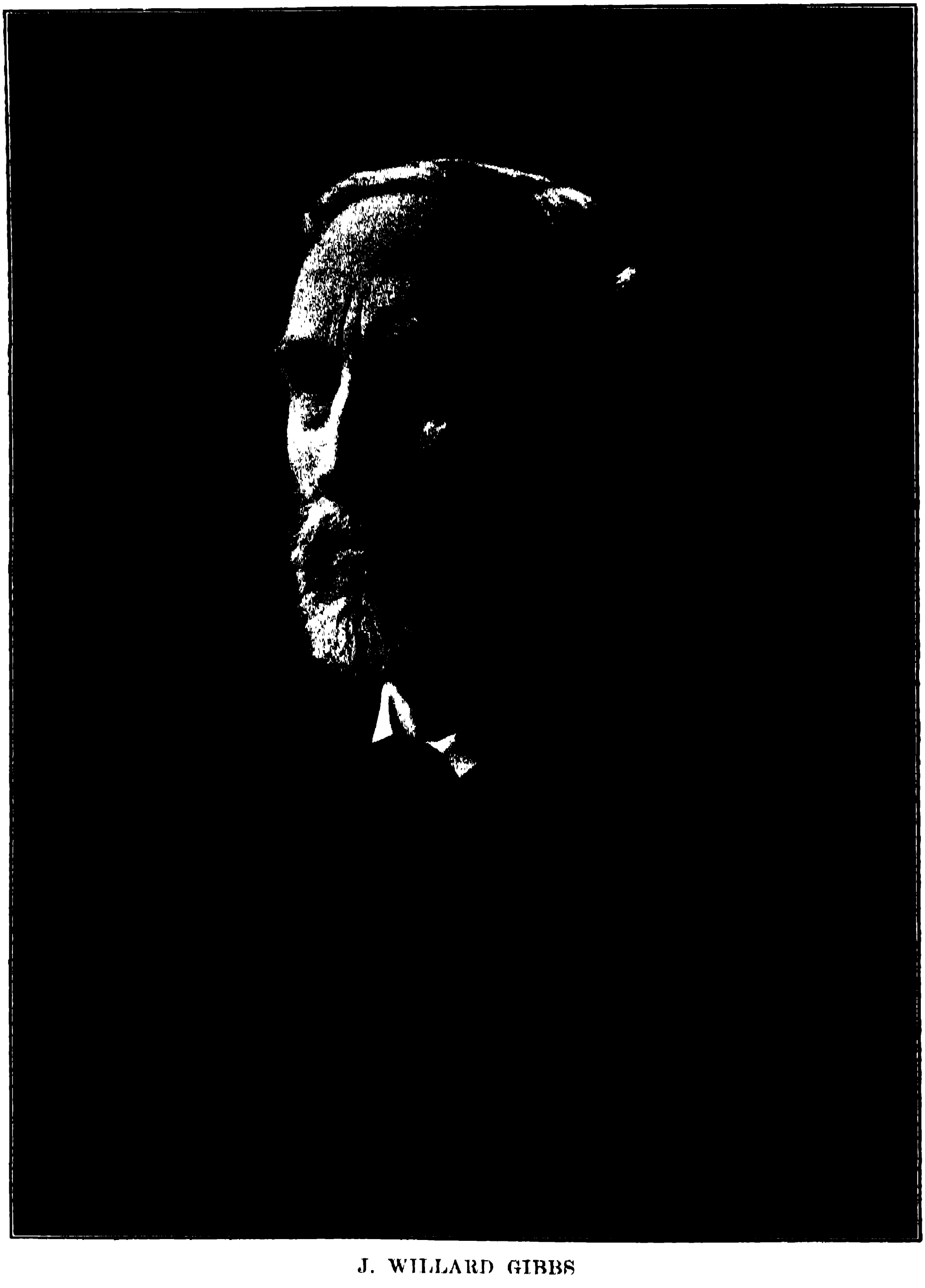
Another superb avenue palm which was sent in, a native of Malaya, was *Actinorhytis calapparia*, a species which requires for its full growth less than half the space that the Royal Palm does. The sealing-wax palm (*Cyrtostachys renda*), which is characterized by having the most beautiful scarlet colored leaf-sheaths imaginable, has become a common dooryard palm in the private residences of Medan, Sumatra. I thought it was the handsomest dooryard palm I had ever seen and secured as much seed as I could. The semi-aquatic Nipa palm (*Nipa fruticans*) had not yet been established on the coast of South Florida nor so far as I know anywhere in the whole Western Hemisphere, and I trust that the seeds secured may establish it there. It is a denizen of the brackish waters of the coastal plains of the Orient and is one of the most useful palms there. Why that incomparable palm of the Indo-Malayan Region (*Onchosperma filamentosa*) has not been widely naturalized in the tropics of the American

continents I do not know, for of all the graceful species of this peculiarly graceful order of plants they are among the finest. Their incomparably slender trunks, which grow in clusters of twenty or so, rise from bases which are not over six or eight inches in diameter to a height of fifty feet and bear at their tips long waving plumes of foliage.

When I read this brief catalogue of plants which the expedition collected, I am conscious that my enthusiasm regarding the various species may smack of "counting one's chickens before they are hatched," but nevertheless it is not a mere catalogue, for there are now hundreds of thousands of these small plants growing larger every day in pots or boxes or in rows in the various plant introduction gardens of the Department of Agriculture, and these will show in time what they are going to do in their new homes.

The Allison V. Armour Expeditions may not have very materially widened the horizon of the known, but they have made available to thousands of experimenters rare and valuable living plant material for experimental use which they could probably never have had otherwise. Out of some of these plants I am confident things of real wealth and use will come with the lapse of years.

The scientific observations on ants and other insects which Dr. Wheeler made in the Canaries and Balearic Islands have some of them been already published. The materials collected by Dr. McKinney, which have a direct bearing upon the obscure virus diseases of cultivated plants, have, I believe, already contributed valuable data for his researches, and the observations and collected materials which Dr. Dalziel made on the West Coast of Africa may be expected to be of distinct value in the completion of the Flora of West Africa upon which he is engaged.



J. WILLARD GIBBS

WILLARD GIBBS, AN APPRECIATION

By Dr. JOHN JOHNSTON
DEPARTMENT OF CHEMISTRY, YALE UNIVERSITY

IT is somewhat of an anomaly that the fiftieth anniversary of the publication, in the *Transactions* of the Connecticut Academy, of the first part of Gibbs's great work on the equilibrium of heterogeneous substances should have been signalized in Holland by the publication of a Gibbs number of their chemical journal, the *Chemisch Weekblad;* whereas few, if any, in America took thought of the matter at all. It is furthermore anomalous that the contributors to this number should include besides the Hollanders (W. P. Jorissen, J. D. van der Waals, Jr., F. A. H. Schreinemakers, J. J. van Laar, J. W. Terwen), a Frenchman (H. LeChatelier) two Germans (W. Ostwald, G. Tammann), a Canadian (W. Lash Miller) a Norwegian (J. H. L. Vogt), two Englishmen (F. G. Donnan, F. A. Freeth), but no American. Truly a prophet is not without honor save in his own country.

This is instanced in another way. Quite a number of foreigners visiting Yale have asked about a memorial to Gibbs, and have expressed astonishment at the reply that there is none, apart from a bas-relief on the stairway of the Sloane Physics Laboratory,—and this bas-relief is the gift of Professor Walther Nernst, of the University of Berlin. One visitor, a distinguished Swedish scientist, was not satisfied until he had laid a wreath upon Gibbs's grave. This is a condition of affairs which, it is expected, will soon be remedied by the establishment at Yale University of an appropriate memorial in the form of a Willard Gibbs professorship. Those appointed to this professorship would, it is contemplated, be men from other institutions qualified to give a course of lectures, extending over one or two terms, in some branch of chemistry, physics or mathematics, particularly in those fields especially associated with the name of Gibbs; and they would be considered as temporary members of the faculty giving courses regarded as a regular part of the university curriculum. The rotation of eminent men, from many countries, each an outstanding figure in his own line of work, would serve as an inspiration to faculty and student alike, and thus would constitute a continuous and effective memorial to Gibbs.

At present one can merely adopt the epitaph to Sir Christopher Wren "Si monumentum requiris, circumspice," in suggesting that the visitor read Gibbs's papers and ponder their manifold practical consequences, both direct and indirect. But his most important papers are again out of print and difficult of access, as indeed they have been for a considerable fraction of the period since their first publication. This difficulty will soon be removed by the publication —arrangements for which are well under way—of an inexpensive reprint of his works. But another difficulty remains, for Gibbs's reasoning is so rigorous that few people have been willing to study his works sufficiently to grasp their full implications; for to him "mathematics is a language," as he is reported to have stated in a faculty meeting engaged upon the Sisyphean task of determining the course of study to be pursued by the average student. This difficulty of interpretation may, it is hoped, be alleviated by the publication of a volume, or volumes, in which his work would be amplified and explained, with illustrations of its application to some of the multifarious experimental cases which have in the meantime been investigated;

arrangements are now under way to have these essays written by those most competent in the special fields. This should serve to widen the appreciation of Gibbs's contribution to natural philosophy; for, particularly as regards many of the developments of great economic value, those who have benefited are quite unaware of the fact that without Gibbs's work these developments would not have been possible. Nor is it a case of which it may be asserted that some one else would have done it; this would be true with respect to isolated theorems, but only a genius of the first order could imagine and arrange the whole as a connected philosophy. It may well be remarked here that no mistake has yet been discovered in Gibbs's work--the accumulation of experimental observations has merely verified his predictions, and in no case run counter to them—though in the fifty years since publication many principles and theories of physical science then generally accepted as fundamentally true have proved to be incompletely valid or even erroneous.

Before endeavoring to set forth what was achieved by Gibbs let us recall the main facts of his life. Josiah Willard Gibbs was born in New Haven, February 11, 1839, the fourth child and only son of Josiah Willard Gibbs, professor of sacred literature in the Yale Divinity School, and of his wife Mary Anna, daughter of Dr. John Van Cleve, of Princeton. He entered Yale College in 1854, graduated in 1858, and continued his studies in New Haven until 1863 when he received the degree of doctor of philosophy, the title of his dissertation being "On the Form of the Teeth of Wheels in Spur Gearing."[1] He then spent three years as a tutor, the first two in latin, the last in natural philosophy, and in 1866 went to Europe, first to Paris, then to Berlin and finally to Heidelberg, where at that time both Kirchhoff and Helmholtz were active. In 1869 he returned to New Haven, and in 1871 he was appointed professor of mathematical physics in Yale College, a position which he held until his death, April 28, 1903. Scientific honors of all kinds came to him, degrees, membership in academies and other learned societies; and he was in correspondence with Kelvin, Clerk Maxwell, Boltzmann and other contemporary European leaders in mathematical physics.

In 1873, when thirty-four years old, he published in the *Transactions* of the Connecticut Academy two papers, one entitled "Graphical Methods in the Thermodynamics of Fluids," the other "A Method of Geometrical Representation of the Thermodynamic Properties of Substances by Means of Surfaces"; and, following these, in 1876 and 1878, the two parts of the great paper "On the Equilibrium of Heterogeneous Substances" which is generally "considered his most important contribution to physical science, and which is unquestionably among the greatest and most enduring monuments of the wonderful scientific activity of the nineteenth century" (Bumstead[2]). His subsequent principal writings, in the years 1881–1893, deal with multiple algebra and vector analysis (the latter finally published in 1901 as a treatise edited by Professor E. B. Wilson); with the electromagnetic theory of light, a series which appeared between 1882 and 1889; and lastly a work entitled "Elementary Principles in Statistical Mechanics," in which he returned to a theme closely connected with his work on thermodynamics. At his death were found a few fragments, intended as portions of a supplement to the "Equilibrium of Heterogeneous Substances"; these are published in the "Scientific Papers." It is of interest to

[1] This dissertation has never been printed; the original manuscript is preserved in the Yale Library.

[2] "The Scientific Papers of J. Willard Gibbs" edited by Henry Andrews Bumstead and Ralph Gibbs Van Name; 2 volumes, 1906. (Vol. I is now out of print.)

note that one of the topics he proposed to treat is "entropy as mixed-up-ness," a point of view which during the last few years has been widely adopted.

With respect to his personal characteristics I can not do better than quote from the biographical sketch prefixed to volume I of the "Scientific Papers."

Outside of his scientific activities, Professor Gibbs's life was uneventful; he made but one visit to Europe, and with the exception of those three years, and of summer vacations in the mountains, his whole life was spent in New Haven, and all but his earlier years in the same house, which his father had built only a few rods from the school where he prepared for college and from the university in the service of which his life was spent. His constitution was never robust—the consequence apparently of an attack of scarlet fever in early childhood—but with careful attention to health and a regular mode of life his work suffered from this cause no long or serious interruption until the end, which came suddenly after an illness of only a few days. He never married, but made his home with his sister and her family. Of a retiring disposition, he went little into general society and was known to few outside the university; but by those who were honoured by his friendship, and by his students, he was greatly beloved. His modesty with regard to his work was proverbial among all who knew him, and it was entirely real and unaffected. There was never any doubt in his mind, however, as to the accuracy of anything which he published, nor indeed did he underestimate its importance; but he seemed to regard it in an entirely impersonal way and never doubted, apparently, that what he had accomplished could have been done equally well by almost any one who might have happened to give his attention to the same problem. Those nearest him for many years are constrained to believe that he never realized that he was endowed with most unusual powers of mind; there was never any tendency to make the importance of his work an excuse for neglecting even the most trivial of his duties as an officer of the college, and he was never too busy to devote, at once, as much time and energy as might be necessary to any of his students who privately sought his assistance.

Although long intervals sometimes elapsed between his publications his habits of work were steady and systematic; but he worked alone and, apparently, without need of the stimulus of personal conversation upon the subject, or of criticism from others, which is often helpful even when the critic is intellectually an inferior. So far from publishing partial results, he seldom, if ever, spoke of what he was doing until it was practically in its final and complete form. This was his chief limitation as a teacher of advanced students; he did not take them into his confidence with regard to his current work, and even when he lectured upon a subject in advance of its publication (as was the case for a number of years before the appearance of the "Statistical Mechanics") the work was really complete except for a few finishing touches. Thus his students were deprived of the advantage of seeing his great structures in process of building, of helping him in the details, and of being in such ways encouraged to make for themselves attempts similar in character, however small their scale. But on the other hand, they owe to him a debt of gratitude for an introduction into the profounder regions of natural philosophy such as they could have obtained from few other living teachers. Always carefully prepared, his lectures were marked by the same great qualities as his published papers and were, in addition, enriched by many apt and simple illustrations which can never be forgotten by those who heard them. No necessary qualification to a statement was ever omitted, and, on the other hand, it seldom failed to receive the most general application of which it was capable; his students had ample opportunity to learn what may be regarded as known, what is guessed at, what a proof is, and how far it goes. Although he disregarded many of the shibboleths of the mathematical rigorists, his logical processes were really of the most severe type; in power of deduction, of generalization, in insight into hidden relations, in critical acumen, utter lack of prejudice, and in the philosophical breadth of his view of the object and aim of physics, he has had few superiors in the history of the science; and no student could come in contact with this serene and impartial mind without feeling profoundly its influence in all his future studies of nature.

In his personal character the same great qualities were apparent. Unassuming in manner, genial and kindly in his intercourse with his fellow-men, never showing impatience or irritation, devoid of personal ambition of the baser sort or of the slightest desire to exalt himself, he went far toward realizing the ideal of the unselfish, Christian gentleman. In the minds of those who knew him, the greatness of his intellectual achievements will never overshadow the beauty and dignity of his life.

This estimate of his character is corroborated and illustrated by letters found among his papers, many of which

are quoted below. These few letters, along with a much larger number of letters written to him, are preserved by the Van Name family (his niece and nephews) who have kindly permitted me to examine them and to use such as are of immediate interest. A perusal of this correspondence shows that many of the letters had not been preserved by Gibbs; for, though amongst the writers there are a number of conspicuous names, others, equally outstanding (for instance, Clerk Maxwell) who are known to have written to Gibbs, are missing. The few letters written by Gibbs himself—for this was before the time of typewriters and carbon paper for professors—are apparently either first drafts or copies which he had kept for reference.

To Professor J. P. Cooke who had requested him to write, for the *Proceedings* of the American Academy, "an appreciatory notice of the life-work" of Clausius, one of the founders of the science of thermodynamics, Gibbs replied:[1]

New Haven, June 10/89.

Professor J. P. Cooke,
My dear Sir:

The task which you propose is in many respects a pleasant one to me, although I have not much facility at that kind of writing, or indeed, at any kind. Of course, I should not expect to do justice to the subject, but I might do something.

There are some drawbacks: of course it has not escaped your notice that it is a *very* delicate matter to write a notice of the work of Clausius. There are reputations to be respected, from Democritus downward, and susceptibilities which may be hurt, if not of the distinguished men directly concerned, at least of their hot-headed partisans.

Altogether I feel as if I had to take my life in my hands.

Without making a positive engagement at this moment, as soon as I can get a little relief from some pressing duties, I will look the matter up and see what I can do, and will communicate with you further.

Yours truly,

J. W. G.

[1] The notice of Clausius which appeared in Proc. Am. Acad., 16, 458 (1889), is reprinted in the Scientific Papers, Vol. II.

Maxwell was apparently the first to note the significance of Gibbs's work, for in 1875 he wrote in *Nature* (vol. 11, p. 357): "I must not omit to mention a most important American contribution to this part of thermodynamics by Professor Willard Gibbs, who has given us a remarkably simple and thoroughly satisfactory method of representing the relations of the different states of matter by means of a model. By means of this model, problems which had long resisted the efforts of myself and others may be solved at once." Maxwell's insight is shown by the statements, made in 1876, that the methods introduced by Gibbs "are likely to become very important in the theory of chemistry" and "more likely than any others to enable us, without any lengthy calculations, to comprehend the relations between the different physical and chemical states of bodies." He was indeed so much interested that he sent to Gibbs a plaster model, constructed with his own hands, to illustrate the correlated changes in volume, entropy and energy of water-substance. No letters from Maxwell have been preserved, but we find his interest reflected in letters such as the following:

Darroch, Falkirk, 15/Dec/76

Professor W. Gibbs,
Dear Sir:

Some months ago I had a letter from Professor Clerk Maxwell, of Cambridge, in which he called my attention to some expositions of yours on the thermal equilibrium of bodies in different states. Since then I have "moved heaven and earth" in the shape of printers, publishers, booksellers, agents, etc. to get me a copy of your work but unfortunately all without effect. As a last resource I have ventured to come to you, to ask you to send me such information as will enable me to send for a copy of your work, or if it is not trespassing too much on your time to ask you to have the kindness to order a copy to be sent to me.

I have sent you by this post a copy of a paper of mine on a similar subject. From it you will see that the nature of the vessel in which water is boiled has no influence on the boiling point.

[1] See Maxwell, "Theory of Heat" 8th edition (1885) pp. 195–208.

Water may be raised far above its boiling point in vessels made of metal as well as in glass vessels.

Trusting you will forgive this trespass on your kindness,

I have the honour to remain,

Yours truly,

JOHN AITKEN.

The longest correspondence—which however has clearly not been preserved complete—is with Ostwald; it includes the negotiations which eventually resulted in the publication of a German translation, by Ostwald, of the memoir on heterogeneous equilibrium. The first letter is from Ostwald, then in Riga, who wrote, April 26, 1887, announcing his collaboration with van't Hoff in commencing the publication of the *Zeitschrift für physikalische Chemie,* inviting Gibbs to contribute articles and requesting permission to use his name as one of those associated with the publication; and continued as follows:[2]

I take this opportunity of expressing the wish, shared by many colleagues, that your great memoir, which is fundamental to the application of thermodynamics to chemical problems, be made more readily accessible. Could you not bring yourself to republish it in expanded form, illustrated with specific examples, of which there is now no lack? I must admit that your work is very difficult, particularly for the chemist, who is seldom conversant with mathematical reasoning. I would like it best if you would agree to a German edition. I would be glad to arrange for its publication and to take care of the translation. In this way the study of this domain would be greatly intensified, especially in Germany.

To this Gibbs replied, August 3, 1887:

Dr. W. Ostwald,
My dear Sir:

Please accept my apologies for my delay in replying to your very kind letter. Some points required a certain consideration (the more, as at that time I had not yet seen your valuable journal), and when I had laid your letter aside, the pressure of other engagements prevented me from returning to it.

I am very glad that you have undertaken a journal of this character, for which there seems to be an abundant opening. The subject is one in which I have felt a lively interest, and to which, although my time for the last years has been given almost exclusively to other subjects, I have always hoped to be able to return. Nevertheless I am not able to make any engagements, but can only assure you of my good wishes for your undertaking and my grateful appreciation of your kind interest in my own work,

I remain,

Yours very respectfully,

J. WILLARD GIBBS.

The next letter preserved is from Ostwald, dated November 14, 1888, in which he thanks Gibbs for helping him to secure a copy of the memoir and asks:

Would you be willing that I publish a German translation of your fundamental paper? It is so inaccessible, and contains so much that is important, that such an undertaking seems to me to be very useful.

To this Gibbs replied, December 7, 1888:

Professor W. Ostwald,
My dear Sir:

I should be very glad to have my essays in thermodynamics made accessible to a larger circle of readers. Yet I should have feared that the call for a German edition would hardly justify the labor and expense of the translator and publisher. If, however, you think differently, I should be glad to hear from you more definitely in regard to what you would think practicable.

With thanks for your kind interest in my work, I remain,

Yours truly,

J. W. GIBBS.

Ostwald's translation was published in 1892, but without notes or preface by Gibbs and without his portrait, notwithstanding repeated requests for all three. In 1895, however, Ostwald did prevail upon him to send a negative from which was made the heliogravure published as a frontispiece to volume 18 of the *Zeitschrift für physikalische Chemie* in 1895; from this in turn was made the picture reproduced in this article.

To return now to the paper "On the Equilibrium of Heterogeneous Substances." It is prefaced by the motto, from Clausius,

Die Energie der Welt ist constant
Die Entropie der Welt strebt einem Maximum zu.

[2] Original in German.

As illustrations of the condensed style—a style in which every word counts and no word is redundant—I quote the opening paragraph and the concluding page, between which are some 300 pages of close reasoning in which many important theorems are enunciated, and rigorously derived, for the first time.

The comprehension of the laws which govern any material system is greatly facilitated by considering the energy and entropy of the system in the various states of which it is capable. As the difference of the values of the energy for any two states represents the combined amount of work and heat received or yielded by the system when it is brought from one state to the other, and the difference of entropy is the limit of all possible values of the integral $\frac{dQ}{t}$ (dQ denoting the element of the heat received from external sources, and t the temperature of the part of the system receiving it,) the varying values of the energy and entropy characterize in all that is essential the effects producible by the system in passing from one state to another. For by mechanical and thermodynamic contrivances, supposed theoretically perfect, any supply of work and heat may be transformed into any other which does not differ from it either in the amount of work and heat taken together or in the value of the integral $\frac{dQ}{t}$. But it is not only in respect to the external relations of a system that its energy and entropy are of predominant importance. As in the case of simply mechanical systems, (such as are discussed in theoretical mechanics,) which are capable of only one kind of action upon external systems, viz., the performance of mechanical work, the function which expresses the capability of the system for this kind of action also plays the leading part in the theory of equilibrium, the condition of equilibrium being that the variation of this function shall vanish, so in a thermodynamic system, (such as all material systems actually are,) which is capable of two different kinds of action upon external systems, the two functions which express the twofold capabilities of the system afford an almost equally simple criterion of equilibrium.

. . . .

The foregoing examples will be sufficient, it is believed, to show the necessity of regarding other considerations in determining the electromotive force of a galvanic or electrolytic cell than the variation of its energy alone (when its temperature is supposed to remain constant), or corrected only for the work which may be done by external pressures or by gravity. But the relations expressed by (693), (694), and (696) may be put in a briefer form.

If we set, as on page 89, $\psi = \varepsilon - t\eta$ we have, for any constant temperature, $d\psi = d\varepsilon - td\eta$ and for any perfect electro-chemical apparatus, the temperature of which is maintained constant,

$$V'' - V' = -\frac{d\psi}{de} + \frac{dW_G}{de} + \frac{dW_P}{de} \qquad (679)$$

and for any cell whatever, when the temperature is maintained uniform and constant

$$(V'' - V')\, de \leqq -d\psi + dW_G + dW_P \qquad (698)$$

In a cell of any ordinary dimensions, the work done by gravity, as well as the inequalities of pressure in different parts of the cell may be neglected. If the pressure as well as the temperature is maintained uniform and constant, and we set, as on page 91,

$$\zeta = \varepsilon - t\eta + pv$$

where p denotes the pressure in the cell, and v its total volume (including the products of electrolysis), we have

$$d\zeta = d\varepsilon - t\, d\eta + p\, dv,$$

and for a perfect electro-chemical apparatus,

$$V'' - V' = -\frac{d\zeta}{de} \qquad (699)$$

or for any cell,

$$(V'' - V')\, de \leqq -d\zeta \qquad (700)$$

In the Scientific Papers, Volume 1, this is followed immediately by Gibbs's own abstract, prepared for, and published in *The American Journal of Science*;[1] but a better brief statement for the present purpose is contained in the letter of January 10, 1881, to the American Academy of Arts and Sciences in which Gibbs expresses his appreciation of the award of the Rumford Medal to him by the Academy, and continues:

One of the principal objects of theoretical research in any department of knowledge is to find the point of view from which the subject appears in its greatest simplicity. . . .

The leading idea which I followed in my paper on the Equilibrium of Heterogeneous Substances was to develop the *roles* of energy and entropy in the theory of thermo-dynamic equilibrium. By means of these qualities the general condition of equilibrium is easily expressed, and by applying this to various cases we are led at once to the special conditions which characterize them. We thus obtain the consequences resulting from the

[1] Volume 16, pp. 451–458, 1878.

fundamental principles of thermo-dynamics (which are implied in the definitions of energy and entropy) by a process which seems more simple, and which lends itself more readily to the solution of problems, than the usual method, in which the several parts of a cyclic operation are explicitly and separately considered. Although my results were in a large measure such as had previously been demonstrated by other methods, yet, as I readily obtained those which were to me before unknown, or but vaguely known, I was confirmed in my belief in the suitableness of the method adopted.

A distinguished German physicist has said,—if my memory serves me aright,—that it is the office of theoretical investigation to give the form in which the results of experiment may be expressed. In the present case we are led to certain functions which play the principal part in determining the behavior of matter in respect to chemical equilibrium. The forms of these functions, however, remain to be determined by experiment, and here we meet the greatest difficulties, and find an inexhaustible field of labor. In most cases, probably, we must content ourselves at first with finding out what we can about these functions without expecting to arrive immediately at complete expressions of them. Only in the simplest case, that of gases, have I been able to write the equation expressing such a function for a body of variable composition, and here the equation only holds with a degree of approximation corresponding to the approach of the gas to the state which we call perfect.

Starting from the basis that

For the equilibrium of any isolated system it is necessary and sufficient that in all possible variations of the state of the system which do not alter its energy, the variation of its entropy shall either vanish or be negative,

he proceeds to develop the general relations which determine the attainment of equilibrium in systems of many different kinds, simple and complex, subject to many varieties of restrictive conditions. To convey an idea of the precise nature of Gibbs's achievement is no easy task; and I shall accordingly make free use of what others, better fitted, have written, keeping in mind Stevenson's lines

Of all my verse, like not a single line;
But like my title, for it is not mine.
That little from a better man I stole;
Ah, how much better, had I stol'n the whole!

The Copley medal of the Royal Society was, in 1900, awarded to him as "the first to apply the second law of thermodynamics to the exhaustive discussion of the relation between chemical, electrical and thermal energy and capacity for external work." Larmor in the article "Energetics" in the Encyclopedia Britannica wrote: "His monumental memoir . . . made a clean sweep of the subject; and workers in the modern experimental science of physical chemistry have returned to it again and again, to find their empirical principles forecasted in the light of pure theory, and to derive fresh inspiration for new departures." In announcing Gibbs's death Ostwald wrote merely: "To general chemistry he gave for a hundred years form and content."

In a recent essay entitled "The Influence of J. Willard Gibbs on the Science of Physical Chemistry," Professor F. G. Donnan writes:[1]

It has often happened in the history of science that after or during a period of activity, there has come a man of genius, who, combining profound insight with the highest powers of logical reasoning, has presented the world with a precisely formulated and far-reaching synthesis of scientific principles. We see the first great physical synthesis of this sort in the laws of motion and the theory of universal gravitation as enunciated by Newton in the seventeenth century. The further study of the laws relating to the motion and equilibrium of material bodies culminated in the great and comprehensive formulation due to Lagrange and Hamilton in the eighteenth and early nineteenth centuries.

When we endeavor to trace the history of thermodynamics, we find a similar development; the great step taken by Carnot, the gradual recognition of the general principle of the conservation of energy, the statement of the second law by Clausius and Kelvin, and finally the great, comprehensive, and generalized statement of Willard Gibbs, whose work bears the same relation to the science of thermodynamics that the work of Lagrange and Hamilton bears to the science of mechanics. The wonderful power of profound reasoning and extreme generalization possessed by Gibbs entitles him to an equal rank in an allied branch of science. Clerk Maxwell and Boltzmann, perceiving that in the development of the dynamic theory of gases, the principles of mechanics must be supple-

[1] *J. Franklin Inst.*, *199*, 457–84 (1925).

mented by statistical reasoning, had established the very important science of statistical mechanics. Their investigations applied to a system containing a vast assemblage of molecules in random motion. Gibbs, not content with his generalized analytical and geometrical formulation of thermodynamics as based on the "empirical" principle of entropy, and seeking a rational foundation for this branch of science, turned his attention to statistical mechanics. In characteristic manner, he proceeded to apply dynamical and statistical reasoning not merely to a single assemblage of molecules but to a vast, though unconnected, assemblage or "ensemble" of systems subject to the same dynamical laws and each characterized by a very great number of degrees of freedom. Not only did he obtain the rational foundation of thermodynamics which he sought, but the science of statistical mechanics received an extension and generalization comparable with that given by Lagrange and Hamilton to the science of mechanics.

Writing some fifteen years ago, Henry Adams stated that, after Benjamin Franklin, Gibbs was the greatest man of science America had produced. He might well have added that in the history of the physical science of the seventeenth, eighteenth and nineteenth centuries, Gibbs ranks with men like Newton, Lagrange, and Hamilton, who by the sheer force and power of their minds have produced those generalized statements of scientific law which mark epochs in the advance of exact knowledge.

His memoir was "nothing less than the creation of a complete and perfectly general thermodynamical theory of physico-chemical equilibrium. At the time when Gibbs wrote this paper, very little was known about the physical nature of atoms and molecules, except their relative masses. He saw, however, that a great advance was possible by an extension and generalization of the fundamental principles of thermodynamics, since these can be stated without reference to atomic and molecular magnitudes. As we know from his writings, Gibbs was certainly no disbeliever in, or despiser of, the atomic and molecular concepts. Realizing, however, the meagreness and uncertainty of this knowledge, he determined wisely to build on a sure foundation, and he saw that this foundation was provided by the theory of energy and entropy. The result was the creation of an almost entirely new physico-chemical science, which we may, for want of a better word, call thermodynamic chemistry. This creation by Gibbs of a comprehensive physico-chemical thermodynamics was, and long will be, of enormous importance both for chemistry and physics. However much we may learn about the individual units of the physico-chemical world, we shall always be vitally concerned with certain very important aspects of the average behavior of the "crowd." Perhaps in time statistical mechanics or statistical electro-magnetics will supply all the knowledge we require, but these branches of science have still a long way to travel before that goal is reached. Even in very recent years, the "electron crowd" has come under the sway of thermodynamical methods, as, for example, in the case of thermal ionization and other types of electron emission and absorption.

. . . Van 't Hoff, by his work on the oceanic salt deposits of the Stassfurt district, created the science of experimental mineralogy as a special branch of the theory of heterogeneous equilibria. Nowhere in the world has this science achieved a more splendid development than in the Geophysical Laboratory at Washington. The same theory has revolutionized the study of alloys and much of the science of metallurgy. The glowing iron and steel which pour daily from thousands of furnaces depend for their intelligent understanding and control on the impulse sent forth into the world from the quiet study at Yale University. Has there ever been a greater example of that eternal truth, that from the finest theory is born the finest practice? During the Great War, the safety of Great Britain and her Allies depended at a very critical moment on the ability of an Englishman, Dr. Francis Arthur Freeth (Chief Chemist to the celebrated firm of Messrs. Brunner, Mond and Co.), rapidly to devise well-founded and scientifically controlled processes for the daily manufacture of enormous quantities of ammonium nitrate from mixtures of other salts. Freeth, a devoted and expert disciple of Gibbs, Roozeboom, and Schreinemakers, solved the problem by means of the graphical methods founded on the thermodynamical theory of heterogeneous equilibria. Thus the invisible links of human thought reached across the years from the peaceful study of an American mathematician almost to the very mouths of the guns.

The work and inspiration of Gibbs have thus produced not only a great science, but also an equally great practice. There is, to-day, no great chemical or metallurgical industry which does not depend, for the development and control of a great part of its operations, on an understanding and application of thermodynamic chemistry and the geometrical theory of heterogeneous equilibria.

The very inadequate sketch of Gibbs's work and influence in one field of knowledge, which has been attempted in the foregoing pages, may perhaps suffice to show that he was the founder and creator of the science of physico-chemical thermodynamics. Like Lagrange and Hamilton, he was the great and profound mathematician

(or mathematical physicist) who, utilizing the scientific advances of half a century and applying to them the full power and scope of deductive logic, so extended and generalized the results of his predecessors and contemporaries as to create a new foundation and a new starting point for human effort. At a time when the atomic and molecular theories were still comparatively undeveloped, the work of Gibbs gave to physical and chemical science a fresh impulse of the highest value and the greatest fruitfulness. The mighty wave of this impulse has extended to many allied fields of knowledge, to mineralogy, metallurgy and physiology, and to almost every branch of industrial practice.

As another witness let us take Le Chatelier, who independently had reached particular conclusions already embodied in Gibbs's work, writing (in French) in the Gibbs number of the *"Chemisch Weekblad"*

The work of Gibbs is, from several points of view, of exceptional character. He is the real creator of chemical thermodynamics, having written this new chapter of science at a time when nothing else in this domain existed; and with a single stroke he has brought this knowledge to such a degree of perfection that in fifty years almost nothing has been added. The various men who have considered the same question have only paraphrased his work; they have sometimes supplemented it in detail, but more often they have only applied to particular cases the general laws formulated by Gibbs. He expounded the phase rule in two pages; large volumes have been written to show its manifold applications.

This result is all the more extraordinary in that Gibbs seems to have possessed only slight knowledge of chemistry. He adduces few examples, and those very simple: the solubility of sugar or salt, the dissociation of hydriodic acid; but his discussion of these simple cases may be extended directly to the most varied systems. One wonders sometimes if he really appreciated the range of his formulas and their usefulness to chemists; and is astonished that he should not have troubled to state his results in terms of the measurable quantities which alone interest the chemist.

The great merit of Gibbs is that, starting from the rigorously exact principles of thermodynamics, he investigated all of the consequences which may thence by absolutely rigorous reasoning be deduced. It is a poor method to introduce uncertain hypotheses, as Clausius did, or approximate experimental laws, as van 't Hoff did. It is certainly necessary, in the discussion of actual cases, to make use of approximate laws—such as the ideal gas law, and the Raoult law of dilute solutions—but they should not be used until the train of rigorous reasoning is complete. To introduce them earlier leads to formulas whose degree of approximation is unknown; and this leads to an appearance of uncertainty which in Gibbs's work is entirely absent.

LeChatelier, after describing the steps in his early work on the application of simple thermodynamic methods to the solution of specific chemical problems, continues:

Later, when I became acquainted with Gibbs's original memoir, I found that the laws which I had painfully established were only special cases of his general formula. Neither van 't Hoff nor I had in fact contributed anything new in principle; we had however rendered chemists a service by being the first to bring to their attention laws which no one had recognized in the mathematical formulas of Gibbs.

In the same place, Ostwald writes:

In order to understand Gibbs's work, this most important of all aids towards the development of affinity theory (Verwandschaftslehre), I began to study it after I had succeeded, not without trouble, in obtaining a copy. I found it hard reading, but recognized its unquestionably very great significance. Prior to this time it had been essayed by very few men, amongst whom were Clerk Maxwell and van der Waals, who both had mentioned and used it. To grasp it more thoroughly I found no better means than to translate the paper word for word; it cannot be abstracted, for, being written in such condensed form, no further abbreviation is possible. Moreover it seemed to me that an edition in German would bring to light this long hidden treasure and thus contribute to the progress of science.

This memoir had a very great influence upon my own development. For Gibbs, although he does not mention it expressly deals exclusively with energy factors, free from any kinetic hypotheses whatever. For this reason his conclusions are as certain, as permanently true as any that are humanly obtainable. Indeed, no error, either in his formulas or in his conclusions, or—what is still more difficult of achievement—even in his postulates has yet been discovered. For not a few scientific papers, based on the most rigorous logic and mathematics, are nevertheless worthless because they imply assumptions and conditions which are not valid; but this confusion is altogether absent from the work of Gibbs.

In his preface to the German translation of the thermodynamic papers, Ostwald wrote in 1892—and his last point is just as true now as it was then:

> The importance of the thermodynamic papers of Willard Gibbs can best be indicated by the fact that in them is contained, explicitly or implicitly, a large part of the discoveries which have since been made by various investigators in the domain of chemical and physical equilibrium and which have led to so notable a development in this field. . . . The contents of this work are to-day of immediate importance and by no means of merely historical value. For of the almost boundless wealth of results which it contains, or to which it points the way, only a small part has up to the present time been made fruitful. Untouched treasures of the greatest variety and of the greatest importance both to the theoretical and to the experimental investigator still lie within its pages.

Some of those already quoted have adverted by implication, if not directly, to the purely practical consequence of Gibbs's work; but this can be supplemented by direct statements. For instance, Tammann writes in the *Chemisch Weekblad* (Vol. 23, 422 (1926)):

> There is undoubtedly no abstract theoretical contribution to science which has exerted such a decisive influence upon the building of a scientific foundation for the basic industries as has that of Gibbs on heterogeneous equilibria. It is doubtful in how far he foresaw the applications of his theorems to practical questions such as the constitution of alloys, roasting and smelting processes, the production of refractories or of fluid slags and their equilibrium with liquid metal. In a general theory there is apparently a power which exceeds that of its creator; it proves to apply to regions extending away beyond the field of view of its originator.
>
> Gibbs's basis was wholly the principles of thermodynamics as developed during his lifetime; but he applied these principles not only to the change of state of single pure substances, as others had done, but also to mixtures of two or more substances. For this purpose he devised other new thermodynamic functions which led him to a series of fundamental theorems, to the phase rule and to theorems as to special points on equilibrium curves, all of which are of lasting significance to experimental chemistry. . . .
>
> We now command not only methods which enable us to describe precisely the mutual behavior of two substances through a wide range of temperature and pressure, and to specify whether the solid phase will consist of a single kind of crystal or of mix-crystals over a range of composition; but we also have, for many of the most important substances, binary and ternary equilibrium diagrams which have become the solid foundation of many technical processes by enabling us to interpret the structure as seen through the microscope, of many materials of construction, such as steels, brasses and bronzes. These diagrams are of many different forms, yet they are all subject to one rule, the phase rule of Gibbs. Thus the abstract theoretical investigations of a studious recluse constitute the scientific basis for the main part of the knowledge of the modern metallurgist.

In the same place there is a short article by Donnan on "The Phase Rule of Gibbs in Industry," in part as follows:

> In the carrying out of chemical and metallurgical processes on an industrial scale it happens usually that we have to deal with the interactions and chemical equilibria occurring in a heterogeneous system containing several phases, whether gaseous, liquid or solid. Furthermore, whatever may be the process in question, we are almost invariably faced with the final problem of separating the desired substance or substances in a sufficiently pure form by such familiar processes as liquation, crystallization, solution, distillation, sublimation, absorption, "salting-out," etc., etc., so that in all these fundamental "Unit Operations" of chemical industry we have to deal with the phase-equilibria of heterogeneous systems. These general remarks will suffice to indicate the fundamentally important role which a study of heterogeneous equilibria plays in the whole vast range of chemical and metallurgical processes. A knowledge of how to predict, control and utilize to the best advantage the equilibria occurring in heterogeneous systems is one of the "philosopher's stones" of modern chemical industry, whereby the base metal of empiricism is transformed into the gold of scientific efficiency.

Other statements illustrating the economic importance of this abstruse imaginative investigation could readily be found; but they are unnecessary. Suffice it to say that most of the industrial applications made hitherto are based on the Phase Rule which, stated by Gibbs in a couple of pages, has required for its exposition books containing many hundreds of pages. And yet the phase rule is only

a qualitative statement, its essence being that the number of independent variables upon which the equilibrium state of any given system depends, is decreased by one for every phase present; it tells us the number of variables but does not predict the *magnitude* of the effect produced by changing them. Its derivation was, in a sense, incidental to the task which Gibbs set himself—namely to formulate exact quantitative relations between the various factors influencing the equilibrium. These quantitative relations themselves, and the other theorems of Gibbs, when they are expounded and illustrated as the phase rule has been, and thus become more generally understood, will without doubt also yield results of great practical significance and importance.

In conclusion, may I apply to Gibbs his own very apt words to be found in his notice of Clausius and of his colleague Hubert Anson Newton, the astronomer:

> The constructive power thus exhibited, this ability to bring order out of confusion, this breadth of view which could apprehend one truth without losing sight of another, this nice discrimination to separate truth from error,—these are qualities which place the possessor in the first rank of scientific men. . . . But such work as that of Clausius is not measured by counting titles or pages. His true monument lies not in the shelves of libraries, but in the thoughts of men, and in the history of more than one science.[1]
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> But these papers show more than the type of mind of the author; they give no uncertain testimony concerning the character of the man. In all these papers we see a love of honest work, an aversion to shams, a distrust of rash generalizations and speculations based on uncertain premises. He was never anxious to add one more guess on doubtful matters in the hope of hitting the truth, or what might pass as such for a time, but was always willing to take infinite pains in the most careful test of every theory. To these qualities was joined a modesty which forbade the pushing of his own claims, and desired no reputation except the unsought tribute of competent judges.[2]

Note: The attention of the reader is directed to an interesting article "Josiah Willard Gibbs and his Relation to Modern Science," by F. H. Garrison, in THE SCIENTIFIC MONTHLY, vol. LXXIV, 470–484; 551–561; vol. LXXV, 41–48; 191–203 (1909). There is also a brief article "Josiah Willard Gibbs and the Extension of the Principles of Thermodynamics" by F. W. Stevens in a recent number of *Science* (Vol. 66, 159–63, 1927).

[1] "The Scientific Papers of J. Willard Gibbs," Vol. II, pp. 263, 267.

[2] ibid., p. 282.

THE ATOM AS A SOURCE OF ENERGY

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ATOMIC physics is generally supposed to deal with theories too abstract to be of practical interest. Yet the recent history of applied science shows that many discoveries in physics which at first seemed to possess only theoretical significance, afterwards proved to be of fundamental importance to the evolution of engineering, and to the evolution of civilization.

For example, Maxwell's ingenious electromagnetic theory of light remained nothing but a theory for fifteen years after its publication in 1873. Thereafter, Hertz, guided by Maxwell's "Treatise," carried out his marvelous experimental work which demonstrated the actual existence of electric waves. Even after this, seven years passed before practical ingenuity created wireless telegraphy based on these Hertzian experiments. Could a student of Maxwell's difficult treatise have foreseen in 1873 what the world would owe to it some day? Could he have pictured that a ship in mid-ocean, alone and in distress, would be able to call for help and to have steamships rushing to its assistance from points hundreds of miles away; or that the lonely rancher in his distant shack might be able to participate, through the medium of a receiving set, in the artistic and intellectual pleasures of the remote metropolis?

The nineteenth century has often been called the century of electricity. Its second half has given us a vast number of important electrotechnical inventions, nearly all of which are based on scientific discoveries made during the first half of the nineteenth century. The first decades of the twentieth century have witnessed a new advance in physics which has been more rapid and more revolutionary than any in the whole history of science. In this short space of time, a new branch of physics has arisen which deals with the structure of the atom, and this field has already become a department of science full of the most marvelous revelations.

No physicist, however, is able to predict to-day that the remainder of the twentieth century will see the technical exploitation of the theoretical discoveries of our age. Were humanity to succeed in harnessing the enormous forces of nature dormant within the atoms, this achievement would inevitably mark a revolution of civilization undreamt of in the wildest speculations.

Indications of the tremendous internal energy of the atom to which I have just referred became evident to physicists through a remarkable and, for a time, quite inexplicable phenomenon which was observed soon after the discovery of radium—that is, during the last years of the past century. It became apparent that every preparation of radium unceasingly produces an immense amount of heat. For example, a preparation containing one kilogram of radium would be capable of raising the temperature of one liter of water from its freezing point to its boiling point within forty-five minutes, and could repeat this process for an apparently infinite number of times.

When this vast and seemingly inexhaustible heat-producing power of radium was discovered, physicists at first

confessed themselves completely baffled, for they could not imagine where this enormous amount of energy could possibly come from. Some conjectured that it was due to an unknown form of energy diffused in the air which was, so to say, stored up in the radium and again given off by it. Others found it necessary to go even further and began to doubt a fundamental law of physics which states that energy can never arise spontaneously.

In spite of the many theories brought forward to account for the strange phenomenon, the riddle of radium remained unsolved until the first years of the twentieth century, when a new scientific truth began to gain ground. Up to that time physicists and chemists considered atoms to be indivisible and, above all, immutable. Then they began to recognize quite clearly that atoms are themselves composed of smaller, electrically-charged particles, and that under certain conditions such particles might be split off from the atom and in this way might alter its chemical characteristics.

Let us see how this conception of atomic structure serves to explain the mysterious heat-production by radium. It has been known for a long time that electrically-charged bodies act upon one another. The force so exerted is one of attraction if the one body is charged positively and the other negatively, and one of repulsion if both bodies are charged positively or both negatively. These electrical forces increase as the distance through which they act decreases. In fact, the force increases in the inverse ratio to the square of distance, so that its strength is increased one hundredfold if the distance between the bodies is reduced to one tenth. Therefore, it becomes clear that within the submicroscopic sphere of the atom comparatively enormous forces are in operation between the particles, and consequently, we must attribute to the atom a very great internal energy. Part of this energy can be liberated and thus become observable either if a change takes place in the internal grouping of these small particles, or if such particles are split off.

On the basis that such sub-atomic processes take place within radium atoms, the unceasing spontaneous production of heat is not difficult to explain. All we have to assume is that a certain percentage of the atoms of a preparation of radium undergo disintegration concomitant with the loss of an atomic particle.

This assumption is more than a mere working hypothesis. It has been verified by observation and experiment. Not only has the gradual transmutation of radium into another chemical element been proved beyond doubt, but it has also been possible to detect swarms of minute, electrically-charged particles which are continuously emitted with enormous velocity by every preparation of radium.

Although the idea of the divisibility and transmutability of atoms clears up the mystery of the heat-production of radium, this phenomenon could not be fully accounted for until much more was known about the interior structure of the atom. Since 1911, physicists have known that every atom has a nucleus charged with positive electricity, its volume being only an infinitesimal part of the volume of the whole atom. They know, further, that, revolving round this nucleus like planets round the sun, there are negative primordial particles, so-called electrons. These planetary electrons (as I shall call them for short) all carry the same charge and possess the same mass; it is their number which determines the chemical character of the atom. In the atom of hydrogen only one such planet revolves round its nucleus. There are three in an atom of lithium, 29 in one of copper, 82 in one of lead

and 92 in one of uranium, the heaviest of all atoms known at present. The mass of a single electron is insignificant in comparison with the mass of the whole atom. A single electron constitutes only one 1847th part of the mass of the lightest of all atoms, the hydrogen atom. Thus, practically, the whole mass of atoms is formed by their nuclei.

Nuclei of atoms are themselves composed of electrons and hydrogen-nuclei, but not directly, for we find that electrons and hydrogen-nuclei form their own small aggregates, which in turn build up the nuclei of atoms. Among these aggregates, the so-called alpha-particles are especially important; each of these alpha-particles consists of four hydrogen-nuclei and two electrons. Thus they form groups of four positive and two negative primordial particles. These alpha-particles are identical with the atomic nuclei of the second lightest element, helium, which lately became fairly well known to the general public because of its use in inflating airships.

The linear dimensions of the nuclei are much smaller than those of whole atoms. Hence it follows that the internal energy of a nucleus is many times as great as that of the planetary system surrounding the nucleus. According to the law already mentioned, the electrical forces acting within the nucleus must be about a million times as great as those which act between the nucleus and the planetary electrons.

The great heat production of radium is due to processes which take place within the nuclei of atoms of radium. In consequence of the disintegration of nuclei, particles split off from them and leave with immense velocity. If these particles are stopped by any substance enveloping the radium, they lose their mechanical energy, which then becomes transformed into heat. The heat production of radium is chiefly caused by alpha-particles ejected from disintegrating nuclei.

These alpha-particles leave the radium-atom with a velocity of about 15,000 to 20,000 kilometers per second. The kinetic energy of an alpha-particle, the mass of which is more than 7,500 times the mass of an electron, is therefore comparatively tremendous. To gain an idea of this energy, picture a swarm of as many alpha-particles as go to build up one milligram of helium, and imagine this swarm flying with the velocity of 15 to 20 thousand kilometers per second. The kinetic energy of such a swarm, whose total weight is only a single milligram, would be several hundred times as great as the kinetic energy of an express train traveling at high speed.

In the space of two or three days any given quantity of radium produces as much heat as the same weight of coal produces during combustion. But there is a great difference between the two materials. The coal becomes ashes after giving off its heat. The preparation of radium seems able to go on producing the same amount of heat forever. Thus we are tempted to regard radium as an inexhaustible source of energy.

More thorough investigation, of course, shows that the inexhaustibility is only apparent. The truth is that, in consequence of the perpetual disintegration of atoms, the quantity of radium present will gradually become less. After twenty years the loss in substance will be about one per cent. This loss is so small that from any practical point of view, radium can be considered as nearly inexhaustible. The total amount of heat which one gram of radium can produce before its complete disintegration has been found to be about half a million times as great as the amount of heat that the same weight of coal generates during combustion. In other words, one could extract from one gram of radium the same quantity of heat as could be obtained from the combustion of half a ton of coal.

The example of the disintegration of radium shows us what enormous energy changes originate in such transmutations of chemical elements. The energy changes exceed those observed in the case of ordinary chemical processes about a million fold (if we consider the same mass of substance involved). An evolution of energy about fifty times greater than that which is caused by the disintegration of radium is to be expected as the result of a possible synthesis of helium from hydrogen.

From a theoretical point of view, such synthesis can be, of course, quite easily understood. It will be remembered that the nucleus of an atom of helium is identical with one alpha-particle and consists of four hydrogen-nuclei and two electrons. If such an alpha-particle forms a nucleus of a helium-atom, it is surrounded by two planetary electrons. The complete helium-atom, therefore, contains altogether four hydrogen-nuclei and four electrons. As each single hydrogen-atom consists of one hydrogen-nucleus and one electron, a formation of a helium-atom from four hydrogen-atoms appears to be possible. It is to be expected that such a transformation will be accompanied by a change of energy, because electrical forces act between the hydrogen-nuclei and the electrons taking part in the synthesis, so that with each alteration in their grouping energy must become liberated or consumed.

Physicists have been able to calculate exactly the amount of energy associated with a synthesis of helium. Their calculations were prompted by the fact that the atomic weight of helium is not exactly four times the atomic weight of hydrogen, as might be expected, but is a little smaller. From this fact physicists inferred that energy is liberated during a synthesis of helium. The difference between the atomic weight of helium and four times the atomic weight of hydrogen is, roughly, eight tenths of one per cent. On this basis the amount of energy liberated through a helium synthesis is enormous. The synthesis of a single gram of helium from one gram of hydrogen would produce as much heat as the combustion of twenty tons of coal. The artificial synthesis of a few milligrams of helium in a laboratory would therefore be sufficient to increase the temperature of the room quite noticeably. Thus the internal energy of the nuclei exceeds the chemical energy of the same quantity of substance from one hundred thousand to many million times.

To realize the proportion between chemical and nuclear energy, consider one gram of some kind of matter to undergo chemical changes, like combustion; there will be liberated a few, but never more than perhaps ten liter-calories from this gram, the liter-calorie being the quantity of heat necessary to raise the temperature of one liter of water by one degree Centigrade. On the other hand, through the disintegration of one gram of radium, that is through the exploitation of nuclear energy, 3,700,000 liter-calories would become liberated, and by means of the synthesis of one gram of helium from one gram of hydrogen even 160 million liter-calories might be gained. By contrast with the few calories obtained by the usual chemical changes, the range of possibilities extends to far more than one hundred million in the case of the synthesis of helium.

Perhaps we may ask whether there is any upper limit to the amount of energy that might be extracted from one gram of matter. Modern physics has led us to recognize that there is such a limit, and has also enabled us to state it exactly. Einstein's theory of relativity answers our query. Every substance that gives off energy suffers a loss in mass, which loss, according to the theory of relativity, can be calculated by divid-

ing the amount of energy given off by the square of the velocity of light. It is necessary in this calculation to use so-called absolute units for all measurements; that is, the mass must be expressed in grams, the velocity of light in centimeters per second and the energy in ergs (a hundred million ergs will do the work which is spent in lifting one kilogram to the height of one meter). The meaning of all this is that the mass of a body which gives off energy of the amount of one liter-calorie is being diminished by one twenty millionth of a milligram.

To visualize how nearly imperceptible such a reduction in mass is, imagine a swimming-pool 50 meters long, 20 meters wide and 2 meters deep, which holds 2 million liters of water. Suppose the temperature of this bulk of water to be lowered by 10 degrees Centigrade. On account of this loss of energy the reduction of mass, which loss has nothing at all to do with evaporation or loss by any other cause, would be just one milligram.

The changes of mass associated with energy changes revealed by laboratory experiments are naturally much too small ever to be measurable. Yet, in the case of astronomical processes, such changes of mass reach very considerable amounts. The sun, for instance, radiates every second enough heat to raise the temperature of one billion billion tons of water (that is, of 10^{18} tons) from its freezing point to its boiling point. This enormous and perpetual expenditure of energy causes a corresponding diminution of mass. We find, by means of a simple calculation, that the sun loses through heat-radiation a mass of 4 million tons per second. This would form a bulk so great that it would require several hundred trains to move it. It is quite interesting to compare the perpetual loss in mass of the sun with its total mass. We find that in ten million years the sun loses something like one millionth part of its mass.

It was stated above that a body in emitting one liter-calorie of energy loses one twenty millionth part of a milligram of its mass. Conversely, a body will lose one milligram of its mass when it gives off twenty million liter-calories. Therefore, twenty thousand million liter-calories must be the upper limit to the amount of energy which, in the most favorable case, could be extracted from one gram of matter.

This is, indeed, an inconceivably great amount of energy. The quantity of energy which is hidden in the mass of a single gram would be more than enough to lift a weight as heavy as all the buildings in New York City put together to the height of the highest skyscraper. Or, to give another example, this amount of energy would also suffice to raise the temperature of all the rooms of all the houses of New York City by several degrees. If we possessed some means by which we could extract from matter its total energy, then, instead of thousands of tons of coal or oil, one gram of matter would be enough to propel the biggest of all ocean-going liners across the Atlantic.

Compared with the maximum energy, the energy which can be tapped through the agency of chemical processes appears insignificant. What are the several calories which we get by means of coal compared with the twenty thousand million calories dormant in each gram of every substance! Even the energy which is liberated by the complete disintegration of radium is one five thousandths of that maximum energy; and further, the energy freed by the synthesis of helium is less than one per cent., to be exact, it is eight tenths of one per cent. of that maximum energy.

Now, the disintegration of radium is a process which has been thoroughly studied and minutely observed by means of all kinds of experiments, and it may be asked, is the so-called transformation of matter into energy, through its complete-

or almost complete dissolution, a physical process, actually taking place, or does it exist only as a vague supposition in the mind of the theorist? For a year or two, physicists have had good reason to assume that such a process actually occurs, and even to assert that it represents the primordial phenomenon in the universe. This enormously important conclusion was arrived at as the result of investigations of the mass of fixed stars. These determinations led astronomers to infer that all stars, during their life-time, lose by far the greater part of their mass.

The life-time of a fixed star is estimated at approximately one million million (or 10^{12}) years, a period so long that the whole duration of the world's history from the days of the ancient Egyptians down to our own time amounts not even to one per cent. of the millionth part of the life-history of our solar system. Astronomy discerns amongst the stars infants and adolescents, adults in the prime of life and ancients; our own sun belongs to this latter group. By comparing the properties of stars belonging to different stages of life, astronomers have been able to trace, to some extent, the life-story of a fixed star. They have recently found out that during its life-time each star gradually loses the greater part of its mass and that this loss can probably only be explained by the assumption that more radical changes are in progress than mere transmutations of chemical elements.

In the interior of the fixed stars we can be sure of temperatures of many millions of degrees. These enormous interior temperatures apparently result in the annihilation of matter as such. Matter, of course, vanishes only when transmuted. In reality, it leaves the star in the form of radiant energy, and in such a way that for each gram of star-mass that vanishes an amount of heat of twenty thousand million liter-calories is produced.

The assumption of a progressive dissolution of matter offers the only satisfactory explanation of a riddle which has puzzled both astronomers and physicists for more than a hundred years. It is the question of the source of the sun's heat. All explanations which attempted to attribute the enormous and permanent radiation of the heat of the sun to chemical or radio-active processes were found to be inadequate. If the sun were made of anthracite, its combustion could only supply a quantity of heat equal to that which is actually radiated in 2,000 years. If we assume that the sun contains radium, its current expenditure of energy could be explained if each kilogram of its mass contained one and a half milligrams of radium. But owing to the permanent disintegration of radium, the heat-radiation of the sun would fall off by one half within something like 1,500 years. This, of course, would not be concordant with the known facts.

If we substitute for radium a radioactive substance of greater longevity, for instance uranium, then the heat-radiation would only be diminished by half after 5,000 million years. But even if the whole sun were made of pure uranium, only about one half the energy permanently emitted could be produced by the disintegration of this element. Besides, the 5,000 million years during which the heat-radiation of the sun thus diminishes by 50 per cent. would be a very small period compared with the life-time of the sun which astronomers assume to be about one million million years. In whichever way physicists and astronomers tried to solve the riddle of the sun's heat, they were unable to find a satisfactory solution. It was only solved by the latest development of physics through the supposition of a gradual annihilation of matter.

So far, I have dealt with the production of energy by matter. But the question inevitably arises as to whether the reverse primordial phenomenon, the generation of matter out of radiation, might possibly also take place in the universe. If this second primordial phenomenon were lacking as the counterpart of the first, then the universe as such would be bound gradually to waste away, and that within a space not longer than perhaps 10^{15} years. We must therefore ask ourselves what becomes of the vast energy which is unceasingly radiated by all stellar bodies into cosmic space. Could this radiation be reconstituted into matter? I will say just a few words about this problem, which was discussed in a paper of mine which was published in the Proceedings of the Vienna Academy of Sciences some months ago.

The idea of a reconstruction of matter from radiation is connected with difficulties arising from the modern conception which attributes an atomic structure also to radiation. The atoms of radiation are called "light-quanta" in modern physics, and the energy of such a light-quantum is found to be proportional to its frequency.

On the basis of this conception, it becomes evident that ordinary radiation could not immediately be transformed into matter. The rays would have to become, as it were, "mature" for this purpose, beforehand. The transmutation into matter would only be possible for rays of a very high frequency. This frequency ought, at least, to be so high that one light-quantum of the rays would possess the same amount of energy as would be liberated by the annihilation of a single hydrogen-atom.

The light-quanta have, as I said, to be made mature for their transmutation into matter. A possible procedure now seems to result from a remarkable phenomenon which was discovered some years ago by Professor Arthur H. Compton, of the University of Chicago. This phenomenon, now generally known as the Compton Effect, consists in the fact that light-quanta experience an observable diminution in their frequency through collisions with particles of matter, especially with electrons. If atoms or nuclei colliding with light-quanta were in enormously rapid motion, then, however, the frequency could also be raised in a considerable degree. Collisions with rapidly moving material particles thus might impart to a light-quantum that critical frequency which qualifies it for a transmutation into a hydrogen-atom.

To this end, it may perhaps only be necessary for a light-quantum to enter a swarm of corpuscles moving with a velocity equal to that with which atomic fragments are expelled in the process of disintegration of radium. If at any time or place there were a kind of gas in the universe whose particles were darting about with such velocities, then this gas might perhaps help to bring about the transmutation of radiation into matter.

I have endeavored to show the rôle of the atom as a source of energy and I have touched on the question of whether, *vice versa,* energy might become a source of atoms. If both these primordial phenomena be realities, the universe would appear to be passing through a cyclical process. Matter would be dissolved in the stars and would turn into radiation, which would again be transmuted into matter and thus, perhaps, give birth to new celestial bodies.

THE METRIC SYSTEM OF WEIGHTS AND MEASURES[1]

By Professor A. E. KENNELLY

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We all know how simple is our system of money based on dollars and cents. We realize that its simplicity depends upon the ten-to-one or decimal relation of its parts. There are ten mills to a cent, ten cents to a dime and ten dimes to a dollar. All sums of money are thus expressed in dollars with decimal steps.

Unlike our money, our system of weights and measures is complicated and difficult. The ten tables taught in our schools comprise about fifty different units, not decimally connected. Very few people can say these tables from memory, without a mistake. The tables taught in English schools comprise about sixty units. Most of the corresponding American and English units are the same; yet there are fourteen that have different meanings. These are the hundredweight and ton, which are long in England, but usually short with us, the pint, quart, peck and bushel in dry measure, the minim, dram and ounce of apothecaries' measure, likewise the gill, pint, quart, gallon and barrel in liquid measure, all of which last are respectively about 20 per cent. larger in Canada and the British Empire than in the United States. We still keep the old wine gallon of Queen Anne; while the British changed, about one hundred years ago, to the imperial gallon. All these fourteen units are ambiguous, and they frequently lead to misunderstandings.

In order to clear up similar complications, the French introduced, about the year 1800, a new system, which they called the metric system, because it was based on a certain new standard yard, called the meter. The meter is only roughly a yard. It is about 10 per cent. longer than our yard. They applied the ten-to-one or decimal steps to this meter, just as in our decimal money system. The metric system came into general use in France about ninety years ago. It was found to be definite and easy. They called one thousand meters a kilometer, from the Greek word for a thousand, and this serves for the measure of great lengths. A kilometer is thus one thousand world yards, or very closely eleven hundred of our yards. One may travel all over continental Europe, by either highway or railroad and find the distances marked off in kilometers. During the great war, two millions of our young men visited France, and so came into contact with the use of the metric system. Since their return to the United States, there has been a distinct increase of popular interest in the metric system. About twenty-five years ago the advocates of this system were mainly scientists; but since the war, mainly business men. There are only three main units in the metric system—the meter, the gram and the liter. The rest are optional names for decimal steps. Thus the distance from Boston to New York, by the New Haven railroad, is 369 kilometers; but that is only another way of saying 369 thousand meters.

The great advantages of the metric system are its widespread international use, its simplicity and its uniformity all over the world. We know that there are two kinds of tons, three kinds of quarts and many bushels; but there is only one meter. This is because there

[1] Given to the air from Station WEEI, Boston.

is only one meter standard, which is preserved in an underground vault in the International Bureau of Weights and Measures at Sèvres, near Paris, France. In 1872, France donated a small old royal palace and twenty-five thousand square meters of land to the International Bureau for this purpose. The old palace at Sèvres stands within the old royal park of St. Cloud. Princess Mathilde once lived there. It is not far from the famous Sèvres porcelain factory, and it has been relinquished by France to international jurisdiction. Presumably, it pays no taxes, and a French policeman could make no arrest there. Facing the old palace, or pavilion, a new laboratory building was erected in 1875, with double walls, to keep the internal atmosphere nearly uniform all the year round. In this laboratory, copies of the international meter bar are made and compared. Each bar is of special platinum alloy, which preserves an untarnished silvery surface. A standard bar has two scratches cut across its face with a diamond, one at each end. The distance along the bar, between these scratches, is set for one meter, when the bar is kept at the temperature of melting ice. Various working copies of the standard meter are kept in the laboratory; but the standard itself is deposited in the vault, eight meters deep below ground. The vault is opened once every six years, in the presence of witnesses, to demonstrate that the standard meter and standard kilogram are in safe preservation. Twenty-eight countries jointly maintain this international bureau. Four special keys are successively needed to open the vault, and three of them are in the custody of foreign delegates to the International Committee; so that the vault can only be opened when the committee meets at six-year intervals. During the great war, one of these keys was in Germany. If it had been necessary to open the vault during the war, it could only have been done by breaking in. Platinum alloy copies of the meter have been distributed among the nations of the civilized world. They are believed to have been correctly compared with the standard at Sèvres, to a precision of at least one part in five millions. There are two of these certified standard meters in the United States, and all our accurate measures of length in industry and in surveying are ultimately connected with these standards. Such standard bars are treated with the greatest care, lest they should be injured by a jolt or fall. Occasionally such national copies of the international meter are returned to Sèvres, for recomparison and check. In all these cases they are taken by a special messenger. It is no wonder, therefore, that the meter has the same length in all parts of the world.

All the civilized countries of the globe have successively either adopted the metric system in their everyday life or they have taken steps officially to do so in the near future, the English-speaking countries only excepted. But although the English-speaking countries have not yet taken any official action towards the general adoption of the system, yet an impartial inquiry into the history of the last thirty years will probably show that we are actually already in process of gradual transition to the metric system, though how many years it will take to make the transition complete no one can say without the gift of prophecy. Substantially all the precise American scientific work is now carried on in the metric system. A few departments of the U. S. government use the system every day; namely, the Coast and Geodetic Survey, a part of the U. S. Customs and the medical departments of the Army and Navy. There is at least one American industry that uses the system exclusively; *i.e.*, the business of making lenses for eye-glasses and spectacles. All such lenses are prescribed and constructed in the metric

system. Many thousands of monthly bills to consumers of electricity for electric light and power, are made out in terms of the kilowatt-hour, a unit based on the metric system. All our radio wave-lengths are measured and specified in meters. A few American manufacturing firms have voluntarily changed over to the metric system in their factories, for the sake of convenience and simplicity. Their testimony has been that while there was a certain inconvenience and bother in making over lists, schedules, drawings and stock-sheets for a little while after the change, the cost was trivial, and no machinery had to be discarded. Our coinage is associated with the system; because a new nickel, or five-cent piece, weighs just five grams, and our silver coins, from the half-dollar down, weigh at the rate of twenty-five grams to the dollar.

Out of the twenty-five large countries and more than fifty little ones that have already given up their original systems and adopted the metric system, none has ever revoked its decision.

A large element of the steadily increasing trend towards the metric system in our country doubtless comes from the fact that modern communication has greatly increased the interchange of methods and ideas between the nations through the telegraph, the telephone and radio.

The invisible radio waves spread from a transmitting station, in all directions, with the enormous speed of light. The radio waves now carrying my voice far and wide are believed to spread over the globe and to reach the furthest opposite point, or antipodes, near Perth in Western Australia, in about one fourteenth of a second of time. The waves from WEEI in Boston have not yet been picked up in Australia, so far as I know; but I am informed, through the courtesy of the officers of WEEI, that the friendly voice has been caught and identified by radio receivers in various remote places as far west as the Pacific coast and as far east in Europe as England, Belgium and Sweden. In the case of more powerful radio-telegraph stations, signals are regularly received at or near their antipodes, just twenty thousand kilometers away, over the seas. This means that in relation to communication of ideas by radio, the most remote countries are only about one tenth of a second apart. We all live on a tenth-of-a-second radio world. It does not seem likely that such a world can indefinitely support more than one system of weights and measures. It must only be a question of time, on a tenth-second world, when only one system will supervene. Will this surviving system be the sixty-unit English system, the fifty unit American system, or the three-unit metric system?

DIET AND DISEASE

By T. SWANN HARDING

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ONE of the easiest and surest ways to make a comfortable living, if you are sufficiently calloused to disregard the sufferings of your dupes and can practice an ample economy of veracity, is to start some system of "eating for health." The way is easy. You can sell an American almost anything if you insist that it will be good for him, and diet systems are exceedingly seductive to laymen. You will require no knowledge of nutrition and no scientific training. In fact these would be decidedly detrimental. They would "cramp your style" and compel you to speak less freely and definitely. What you will need is a dress suit, a hotel rose room, an intimate manner, an alliterative slogan and an eye to the main chance. Then depend on the ladies to find you out, gush and remunerate you munificently for gulling them!

If really good investigators can often become so perverted as to assure us that incorrect eating causes every pathological condition from dandruff to cancer, in spite of the fact that scientific medicine does not yet understand the etiology of either one, we can not, of course, expect too much of these lay prophets of corrective eating. It is a great misfortune, however, that we so sorely lack in these days men who can write popularly and clearly on scientific subjects without sacrificing dignity and exactitude. It is most unfortunate that no writer apparently exists to combat effectually the stream of utterly asinine verbal garbage continually spurting from press and lecture platform on the subject of human nutrition. But would the average editor publish the work of such a writer anyway?

These sciolistic spell-binders would lead you to believe that correct eating will cure any pathological condition at all. Here, as in all cases where exact scientific fact remains incompletely apprehended, systems differ, often diametrically—just as systems of soul salvation necessarily differ. This is because those who propagate systems err by summarizing from too few particulars, by coloring all facts with their doctrinal idiosyncrasies and by speaking inexactly. That is our custom in ordinary life of course. We ascertain a certain few particulars, we generalize forthwith and before we investigate further, we complete our dogma and thereafter absolutely mutilate an inimical fact before we will so much as give it attention. Thus we achieve "universal" truth for all men!

In science such procedure is grossly pernicious. Yet this is the technique of the diet faddist. Let a man recover from influenza soon after he eats a raw onion and he is almost as certain to attribute the prevalence of influenza to an abstinence from raw onions as is a savage to attribute his good luck on a hunt to the jawbone of an ass he found *en route*. Whereas the one will ever thereafter preach asinine jaw-bones as happy hunting omens, the other will prescribe raw onions for anything remotely resembling influenza. There is little to choose here.

But in spite of the sciolists' cacophonous assertions of complete truth and their actual demonstrations of their profound ignorance, a few facts are gradually coming to light which tend to relate faulty diets and certain pathological conditions as cause and effect. A brief and perhaps shamefully inadequate re-

view of this subject is all that is intended here.

Some ideas are surprisingly old. Marco Polo besides coming upon matrimonial and sexual customs in his travels which would make a modern companionate marriage seem morally reactionary, also found certain Asiatics suffering from neck swellings. He attributed these to the water they drank!

In 1600–1700 Florentine pharmacists were selling lemon water ice as an antiscorbutic. In that century any first class Florentine pharmacy was ready to dispense lemonade upon prescription to ward off scurvy.

Ancient Arabian physicians were advanced in many ways. Centuries ago they had elaborately beautiful hospitals in which nervous patients were soothed with sweet music. Each departing patient was presented with a considerable sum of gold in order that he might convalesce without undertaking hard labor at once. Fancy a hospital giving a departing patient money to-day! How we have progressed!

A faint adumbration of modern glandular therapy appears in the fact that the Arab doctors administered dried fox lung to remedy asthma because the fox can run far without fatigue; they also prescribed fox brain for epilepsy on the theory that mental cunning and proficiency could thus be transmitted to remedy the fits. And these procedures were actually just about as sensible as perhaps two thirds of our present day glandular therapy, utilizing, as it so often does, perfectly impotent substances lacking known active principles.

But the Arabs also administered red bone marrow to cure anemia and modern American physicians did not overhaul them in this until about 1890. Finally the Arab physicians constantly emphasized the importance of diet as related to disease prevention. The great Galen also wrote several books on diet and outlined variations therein suited to the age of the patient, his state of health and the time of the year. Hippocrates went so far as to suggest that all diseases originated in the stomach. Modern physicians tend, if anything, to err in the opposite direction and to give nutrition a place altogether too subordinate in etiology. While the blatant cocksureness of the quack lecturer and newspaper prevaricator on diet should not be emulated the physician is somewhat inclined to ignore the definite advances that science has made here.

Quite naturally no exhaustive treatment can be undertaken in a brief paper by a casual student. But some attempt should be made to call attention to the work of certain usually reliable investigators who have shown that faulty diet demonstrably affects physical tone, immunity to infectious, exhaustion, respiratory and gastro-intestinal maladies in addition to its well recognized rôle as an etiological factor in the deficiency diseases. Many leading physicians could be quoted in support of the statement that physicians as a whole are not what they should be when it comes to nutrition in health and in disease. We may, then, venture to proceed.

What shall we attack first among specific conditions attributable to faulty diet? Since such an enormous majority of infants are rachitic or else suffer from a deficiency of iron, this sector seems momentarily seductive. Ed. Mellanby has worked extensively on experimental rickets.[1] He used the following basic diet—lean meat, bread or cereal, yeast, orange juice and olive oil. This diet is deficient in the fat soluble vitamins, bone-calcification is imperfect and rickets follows. But add vitamins—in cod liver oil, egg yolk, whole milk or beef suet and recovery takes place. Cod liver oil will, according to Mellanby, stimulate recovery even if the diet remain low in calcium, although rickets is a calcium deficiency disease; but the other correctives must have calcium fed

[1] *British Medical Journal*, May 24, 1924, 895; Special Report Medical Research Council of Great Britain, No. 93, 1925.

with them in order to be effective. Incidentally the separation of butter and milk very effectually spoils them both for antirachitic purposes.

The more food a young animal eats the faster it grows. A race is at once on between the growth of pre-bone and its calcification into real bone. Cereals seem actually to prevent calcification, oatmeal offending worst of all, white flour and rice not quite so badly. A mixed diet deficient already in the antirachitic vitamin but containing a great deal of oatmeal porridge will rapidly produce bad rickets, the intensity of the disease depending directly upon the amount of oatmeal eaten. Wheat germ is also bad if eaten alone but is so small in amount in whole wheat bread that it can do little harm. Cereals containing large amounts of calcium and phosphorus often deter bone-building most and seem to contain an actual substance preventive of calcification, a substance that cod liver oil alone can completely antagonize. As the muscles become flabby in rickets, weakened bones may be nature's compensation to adjust to poor musculature. So much for Mellanby.

Other investigators do not altogether agree. This is so in very many cases. It argues no deception, no carelessness. It means simply that in such investigation research workers even yet have to do with many unknown factors and with many which it is highly difficult to keep constant. But this mere fact fatally indicts the exponent of perfect diet systems.

Thus, in so far as oatmeal is concerned, certain American workers have recently failed to confirm Mellanby's results and contend that oatmeal does not contain any agent which actively inhibits bone calcification; at least they can find no evidence for this when they attempt to duplicate his experiments exactly. Other workers, as we shall see, doubt that cod liver oil alone, and without additional calcium, can complete a low calcium diet. Finally there is much interesting matter in the work of Cowgill[2] on cereals as a basic diet very easily and simply supplemented to make an ample diet without the use of milk.

Cowgill and coworkers used whole grain cereals, oats, wheat and corn, to comprise from 65 to 80 per cent. of the diet of standard white rats. The only other foods fed were cooked whole egg, cane molasses and lettuce, but the rats retained perfect health. This seems to demonstrate that any whole grain cereal may easily be supplemented with such ordinary common foods to make a complete diet without milk being required at all. With 65 per cent. cereal in the diet, growth, reproduction and lactation all took place normally; with even 80 per cent. the growth of young rats took place unimpeded, though lactation was impaired, but that is a grossly abnormal diet. What is true of young rats is generally true of young humans and any diet which satisfies youth is sufficiently complete for adults, as a rule. Hence it appears that since such food was fed rats "over lengthy periods corresponding roughly to at least the first ten years of man's life span, one is led to suspect that the possibilities in the way of successful nutrition by man on high cereal diets supplemented by relatively few but carefully selected foods other than milk are greater than have been appreciated before." This certainly should sustain those who can not tolerate milk or find it difficult to secure.

Deficient foods also cause bad teeth.[3] While foods containing the fat soluble vitamins—milk, egg yolk, butter, animal and fish fat, cod liver oil—conduce to the formation of good teeth, cereals, especially oatmeal, seem to induce defective teeth, particularly in the absence of vitamins. Certain children were fed the following three test diets:

[2] *Journal* of the American Medical Association, 89, 1770, and 1930, 1927.

[3] *The British Medical Journal*, March 20, 1926, 515.

A—Much milk, some cod liver oil, little cereal (no oatmeal) and other foods to balance.
B—Little milk, much cereal, including oatmeal, and other foods to balance.
C—A diet intermediate between A and B.

The new points of dental decay developed per child while fed these diets were respectively as follows: On diet A, 1.4; C, 2.9, and B, 5.1. This indicates the great deficiency of diet B and the relative excellence of diet A.

Bad diets produce evil effects as visitations upon future generations. Bitches fed defective or rachitic diets produced pups so predisposed to rickets that even a period of good food did not remove the young from the danger of developing rachitic lesions. These diet defects also increased the susceptibility of the young to respiratory diseases like pneumonia and catarrhal conditions, which latter often extend to and impair the alimentary tract. Such deficiencies are really very common in human nutrition and may be responsible for much infant mortality since, in such cases, the proper feeding of the child after it is born is not enough; the pregnant mother must have been properly fed as well.

McCollum has rightly called attention to the insidious effects of a slightly deficient diet over a long period; he has suggested that it lowers vitality, shortens life and advances senility. Dr. Hsien Wu, in an extremely suggestive lecture, "Chinese Diet in the Light of Modern Knowledge of Nutrition,"[4] applied this theory to his own race in particular. The Chinese depend very largely upon vegetable proteins. Their meat consumption *per capita* per day is very low. Vegetable proteins are demonstrably less digestible and less efficient biologically than are animal proteins.

Thus from the standpoint of biological utility wheat protein may be rated 40 per cent., corn meal protein 30 per cent. and pea protein 56 per cent., while milk and ox-meat proteins are 100–104 per cent. The coefficient of digestibility of animal foods is about 97 per cent., of cereals about 85 per cent. and of legumes about 78 per cent.; when legumes and cereals are fed together their coefficient falls below that of either fed alone. The Chinese eat about one seventh as much meat as Americans. Milk is scarce in China and often viewed askance when available. It, therefore, appears that the Chinese have been consistently under-nourished since ancient days when they ate vastly more meat, lived longer and stood taller. To-day the Chinese is peaceful, sequacious, unprogressive, unenterprising, non-persevering; his stature is poor, his physique bad, his mortality high. Dr. Wu is willing to believe that long continued malnutrition over the centuries has contributed much to the present state of his people.

It has, in fact, been observed that California-born Chinese and Japanese actually are better physical specimens than the native-born Asiatics. They eat more in America, too. Then again Gilks and Orr[5] observed that while the Kavirondo of the Victoria Nyanza region have a diet as mixed as the European the prevalent diseases are about the same as those among civilized races. Half the maladies are respiratory; tuberculosis is common and cancer is far from rare. The Mount Kanya natives eat cereals exclusively, with little or no meat, but have poor physiques. The Masai lives on meat, milk and fresh blood but suffers commonly from rheumatism and constipation. A vegetarian diet and abundant sunshine fail to protect the Kikuyu from tuberculosis. Finally, in this incursion into African native diet, the aforementioned Kavirondo follow the curious custom of adding a cow's urine to her milk before drinking it, thus unconsciously augmenting its mineral content.

[4] *Chinese Social and Political Science Review*, January, 1927.

[5] *Lancet*, March 12, 1927, 560.

In passing it is not without interest to emphasize that the following diet seems fundamentally bad—oatmeal, olive oil, milk, meat and yeast, while this one appears experimentally to be basically good—white bread, cod liver oil, milk, meat and yeast!

We turn now to Agnes H. Grant and Marianne Goettsch, fearlessly mentioning the names of original scientific investigators because this is so seldom done. Yet it is much simpler than seeking to avoid mention, it is more honest than posing personally as the original fount of all wisdom and there is no valid reason anyway to deny scientific workers the popular publicity accorded baseball players, adaptive inventors and bankers or industrialists who merely grow rich by commercializing the results of unknown research workers. Let the modest laboratory worker have a name for once![6]

Grant and Goettsch,[7] then, directly studied the nutrition requirements of nursing mothers and the effect of diets deficient in the antirachitic vitamin upon the offspring when mothers eat such diets. McCollum[8] and Hess[9] had separately concluded that if a diet is otherwise satisfactory a mere deficiency in the antirachitic vitamin will not cause rickets when it is fed. Korenchevsky[10] thought otherwise.

There matters stood when Grant and Goettsch attacked the problem and that is why they attacked it. They found that slight dietary deficiencies will, over a considerable period of time, cause diseased conditions which are never produced at all by extreme dietary deficiencies. They found also that the young have rickets only when the antirachitic vitamin is deficient in the diet of their mothers. They demonstrated that the diet of the mother is an exceedingly important factor governing absolutely the increased or decreased resistance of the young to the bad effects of vitamin deficiencies in their own diets. Finally they found that rickets will not develop in young born of well nourished mothers even if these young are actually fed a diet deficient in the antirachitic vitamin.

The rapidity and the severity of the development of rickets in the young really depends very largely upon the depletion of the mother's vitamin reserve during pregnancy. Cod liver oil will actually increase this vitamin reserve while the mother bears and suckles young; the young will then also be very resistant to rickets.

As Cowell[11] observes, it seems apparent that if calcium and the fat soluble vitamins are present in the diet in proper amount rickets may be entirely eliminated, teeth may be vastly improved, infant diarrhoea may be decreased, re-

[6] *A note*—In a recent book review appearing in *The Quarterly Review of Biology* the reluctance of scientific popularizers to mention the names of original investigators was observed. Yet the blame lies very largely upon editors and publishers rather than upon writers. Nothing will more quickly and more certainly confound and horrify the editor of even a "quality" magazine than a few references or a few direct quotations from authorities with names attached. The writer is constantly admonished to omit all references and names of authorities and to pose boldly as an authority himself. Editors of so-called quality magazines consistently under-estimate the mentality of their readers on scientific subjects because they project their own literary intelligences beyond where they should extend. Readers are actually not easily shocked by clearly stated scientific facts, but erring editors with their classic abhorrence of science as a thing no cultured gentleman should be able to understand, constantly confess themselves hopelessly bogged in matters any alert high school student could comprehend. Hence the prettified, storyized, weakly humorous, half spoofing, grossly incorrect rot that passes for scientific popularization in the magazines.—T. S. H.

[7] *American Journal of Hygiene*, March, 1926, Vol. 6, p. 211.

[8] *Proc. Soc. Exp. Biol. and Med.*, 18, 277, 1921.

[9] *J. Biol. Chem.*, 47, 395, 1921.

[10] *British Medical Journal*, No. 3171, Pg. 547 (1921).

[11] *British Medical Journal*, July 31, 1926, 185.

spiratory diseases restricted in virulence and the symptoms associated with malnutrition cleared up. That is simply to say that the diet should contain ample milk, butter and eggs; that there should be constant exposure to sunlight or constant dosage with cod liver oil, which is said to be not so bad if half a banana be eaten immediately thereafter.

We turn to the work of Sherman and MacLeod[12] which at one point contradicts the finding of Mellanby mentioned above. They made a very careful study of the normal calcium content of the bodies of normal rats of different ages and found that the calcium increased in percentage with age. They found that animals fed ample calcium, but stunted in growth by vitamin deficiency, contained more than the normal calcium for rats of the same weight but less than normal for rats of the same age. Furthermore rats fed too little calcium lose calcium from their bones.

Animals fed one sixth whole milk powder and five sixths wheat contained much less calcium than animals fed one third whole milk powder and two thirds wheat, indicating the usefulness of milk as a source of calcium. But unlike Mellanby, these investigators held that the addition of cod liver oil to a diet deficient in calcium would not raise the percentage of body calcium. To do that calcium lactate must be fed in addition to the oil. It is well to record and to attend such differences in order to emphasize the very great complexity of scientific experimentation in nutrition that we may compare therewith the airy and flatulent confidence of the know-it-alls who continuously lecture and write on the subject of diet and disease.

In *The British Medical Journal* for October 25, 1926, there appeared an instructive article by Robert McCarrison, entitled "A Good Diet and a Bad One." This investigator had had excellent opportunities to study middle class diets in England and native diets in India. He fed twenty rats a good diet, such as he says Sikhs eat—whole wheat bread, uncooked cabbage, carrots, fresh fruits, sprouted legumes, potatoes, butter, fresh whole milk and fresh meat. Seventeen lived in good health and of the three which died, two certainly did not die by reason of any nutrition disturbance.

McCarrison also fed twenty exactly similar rats a bad diet, such as Western peoples used—white bread, vegetables cooked in water containing sodium bicarbonate, common salt, a margarine substitute containing 100 grains of boric acid per pound (a common preservative), tinned meat containing the usual chemical preservatives, tinned jam and tea sweetened, then colored with milk. Eleven of these rats died hastily and all were sickly and in poor condition. All these rats suffered from gastro-intestinal and lung troubles and the majority died thereof. McCarrison declares that exactly the same conditions exist among human beings.

Another deficiency causing disease is that of iron. That a young animal is born with a reserve supply of iron is indicated by the fact that its ash will contain about six times as much iron as the ash of the milk fed it in early life. That a diet of milk alone will cause nutritional anemia in young animals beyond the suckling period has repeatedly been observed. That the iron in milk can not be increased by feeding the producing animal additional iron is also well established. Finally it has been demonstrated that iron is readily assimilated from fresh vegetable sources or from inorganic sources if fresh vegetables are also fed. These facts indicate that ample iron supply should be kept in mind in feeding young, growing children so long as milk remains their basic article of diet.

Anemia is, in fact, not an uncommon condition in early life and a little supervision of the diet then will eliminate many illnesses. Outstanding work is

[12] *Jour. Biol. Chem.*, 64, 429, 1925.

being done on pernicious anemia these days by Minot and Murphy and by other investigators. It has, in short, been found that patients with pernicious anemia almost invariably give a history of long continued faulty nutrition and, most fortunately, that the anemia itself may be controlled nutritionally. Using a low fat diet containing fresh fruits and vegetables *ad lib* and much meat, especially kidney and liver, Minot and Murphy rendered nearly all of forty-five pernicious anemia patients absolutely normal and materially helped the remainder. Recent work from McCollum's laboratory indicates that vitamin E, which controls reproduction and is seldom deficient in the ordinary diet, has something to do with the bodily assimilation of iron. If vitamin E is deficient iron assimilation seems to be poor. Liver is unusually high in vitamin E and this may in part explain its efficacy in the regeneration of blood hemoglobin in pernicious anemia.

Whipple and Robscheit-Robbins continued their valuable anemia studies in the December, 1927, *American Journal of Physiology.* They found that the addition of kidney or liver to a diet already rich in iron salts would cause the increased assimilation of iron to be expected from feeding these tissues, but, curiously enough, this increase was always superimposed upon the level of the iron diet. They comment: "It is rare in our experience to find entirely separate factors influencing hemoglobin regeneration which can be combined with complete summation of the two effects." So, bit by bit, the problem of blood hemoglobin regeneration in severe anemia is unraveled.

Another pathological condition that may perhaps be ascribed to faulty diet is stone. Osborne and Mendel suggested in 1917 that stone, or calculi, occurred in the bodies of rats when they were fed a diet deficient in vitamin A.[13] The lack of this fat soluble vitamin seemed to cause a general debility or lowered vitality which favored the invasion of the bladder and urinary passages by bacteria. These bacteria produced an alkaline urine and stones ultimately developed.

Some years later the Japanese Fujimaki[14] apparently confirmed this observation. He found that rats fed a diet deficient in vitamin A developed calculi in the following organs in the order of frequency mentioned—bladder, kidney and bile duct. In some cases the addition of vitamin A to the diet caused the stones to disappear, an argument for milk, butter, eggs and cod liver oil as preventives of stone. It is only fair to say that this work has not yet been pursued far enough to indicate much regarding human beings.

In THE SCIENTIFIC MONTHLY for November, 1927, and in *Popular Science Monthly* for February, 1928, the present writer sought to slay certain common food fallacies. In that article much was said regarding high protein diets and their etiologic rôle in nephritis, constipation and cardio-vascular maladies. Soon thereafter Vilhjalmur Stefansson wrote to the author commending the article but calling attention to the fact that one hundred per cent. meat diets had been fed to human beings without the pathological conditions mentioned developing. As papers in the *Journal* of the American Medical Association for November 23, 1918, July 3, 1926, and May 14, 1927, will show, the Eskimos, a carnivorous race, do not have abnormally high blood pressure, do not suffer unduly from heart and kidney disease and are unconstipated—at least until they adopt the white man's mixed diet. Furthermore, Stefansson himself lived on a one hundred per cent. meat diet for years and survived in excellent health while other men have done this quite success-

13 *Journal* of the American Medical Association, 69, 32.

14 "Progress of Nutrition in Japan"—League of Nations Health Organization, Geneva, 1926, p. 369.

fully right here in America. This work is very suggestive and indicates that high meat diets may not be so pernicious to humans as is generally supposed.

Nephritic diets have long been severe in salt and protein limitations. Yet recent work tends to raise these low limits because it has been shown that some albuminuria of such patients is chargeable to tissue losses of protein which simply must be replaced in the diet. Some investigators indeed now advocate very high protein diets for nephritic patients, though more conservative authorities disagree. At any rate the nephritic patient must get enough protein to prevent debilitation through tissue loss.

As to salt in such diseases, indiscriminate salt restrictions are becoming obsolete. During edema, to be sure, it appears that salt should be restricted to two grams daily but an allowance up to five grams is otherwise permissible. Salt retention is found not always to occur in nephritis. Since normal people get from eighteen to twenty-two grams of salt daily, either directly or cooked into their foods, five grams is little enough, but it does alleviate somewhat the nauseous monotony of a salt free diet.

Physicians have long been too prone to prescribe corrective diets too mechanically and often too readily. These diets are seldom tasty and, while a great convenience to the physician, the patient should be considered too. *The Journal of the American Dietetic Association* recently recorded some most amusing experiments carried on at Harvard Medical School by nascent physicians as part of their course. These youngsters actually ate the pallid and lifeless diets often prescribed for patients. The results were enlightening and, we may hope, chastening. In fact, one conscientious youth struggled so hard to absorb a high fat diet that he was reduced to the atrocious necessity of drinking mayonnaise dressing in his coffee; he then so far forgot himself as to declare that any physician who prescribed such a diet was the kind of fool usually relegated to the lost souls division. Doubtless future patients will benefit from this harsh experience on the part of heroic medical students.

As a whole, then, routine diets are as indefensible in disease as in health. Human beings differ; disease syndromes differ. The old adage was correct—one man's meat is another's poison. Certainly corrective diet will under no circumstances cure whatever ails you, though hundreds of mail order quacks and lecturing faddists endeavor to make you think so.

We have found, however, that nutrition is an important consideration in preventive medicine. Not only does faulty food cause such avowedly "deficiency diseases" as scurvy, beri beri, rickets, optical inflammation (ophthalmia) and pellagra, but gastro-intestinal and respiratory diseases, anemia and even stone may arise from dietary inadequacy. Moreover the faulty diet of mothers is visited upon the next generation in the form of lowered resistance to disease. We have every reason to keep the mysterious internal alchemist, as Paracelsus called him, not only appeased, but supplied with an abundance of best quality raw material.

Many years ago the great Paracelsus wrote:

> The alchemist in each one of us is clever at his business, and just as a prince knows how to employ the best qualities of his servant while leaving the others alone, the alchemist uses the good qualities of our food for nourishment and expels those that would harm us. The alchemist dwells in the stomach, where he works and cooks. He takes the good and changes it into a tincture which he sends throughout the body to nourish all that is in it.

Therefore, the more good qualities the hypothecated alchemist can find the better for us.

RACIAL GROUPS IN A UNIVERSITY

By Professor EDWARD CARY HAYES

THE UNIVERSITY OF ILLINOIS

In view of the discussion of racial traits by a great company of writers, from Gobineau and Vacher de Lapouge to Wiggam and Madison Grant, and in view of current fears as to the mongrelizing of our stock, it occurred to the writer to study the racial groups represented in the University of Illinois. The number of students is sufficiently large to have significance. The individuals are tested for four years in similar pursuits. They come after twelve years of similar schooling. Against such a background of cultural similarity, racial traits might be expected to stand out definitely.

The university department of hygiene which examines every student admitted was asked to record for each student the measurements from which cephalic index is computed, eye color and hair color, distinguishing a number of grades of each, stature, build and racial parentage, as understood by the matriculant.

After thousands of these records had accumulated, a graduate student, Mr. George M. Proctor, was asked to sort out the records of the first hundred Nordics, the first hundred Alpines, the first hundred Mediterraneans, and of all the Chinese, other foreigners, Jews and Negroes encountered. However much doubt there may be as to whether his Nordics, Alpines and Mediterraneans are actually pure-bred representatives of distinct racial stocks, there is no doubt that they are as distinctly classifiable by race as white American citizens ever are.

The investigator was directed to give primary importance to cephalic index and secondary importance to eye color. Hair color and stature were recognized as less significant but treated as corroborative evidence when, for example, blond hair and high stature accompanied a dolicocephalic index and blue eyes, or when medium stature, stocky build and chestnut hair accompanied a brachycephalic index and hazel eyes. The race of their parents, as given by the students, and their names were also treated as having some corroborative value.

The first result of his investigation was that relatively few of the students at this university could be definitely assigned to any racial group. Our student population is very thoroughly mixed in blood and is descended mainly from European populations, each of which is very mixed.

The second fact disclosed was that of those who could be so classified an overwhelming majority were Nordics. Mr. Proctor classified as Nordics about one tenth of the first thousand, but after going through the records for eleven thousand students, he had found only seventy-two whom he felt confident in classifying as Alpines and only ten whom he could classify with confidence as Mediterraneans. Italian parentage and name were not proof of membership in the Mediterranean race. There is too much Lombard and Alpine blood in Italy, and too much departure from characteristic Mediterranean traits was found among those who call themselves Italians.

The Jews were a racially heterogeneous group. Thirty-four per cent. of them had gray, blue or greenish eyes, two had red hair. In respect to cephalic index they were distributed pretty evenly all the way from 72.5 to 88.6, that is, from those very decidedly doli-

cocephalic, through sub-dolicocephalic, meso-cephalic, sub-brachicephalic, to very decided brachicephalic. They showed no tendency to center about a cephalic type. Many of the Jews are indistinguishable in appearance from other Americans. Others among them "look Jewish," that is foreign. The foreignness is often Syrian or Hittite, rather often Spanish. So far as this group of ninety-three indicates, they do not represent a racial type.

The 435 students included in the seven groups treated as classifiable had a scholastic average distinctly below that of the racially unclassifiable mass of students in the university. In this institution a student's grade is computed by counting a grade of A equal to 5, B equal to 4, C equal to 3, D equal to 2 and E equal to 1. E is failure. Each course grade is multiplied by the number of hours' credit given for the course. The sum of these products is divided by the student's total number of credit hours to give his average grade. The average of all the men in the university is found each semester by averaging the averages of a thousand men selected at random. In the nine semesters ending January, 1925, the average grades of all men has ranged from 3.157 to 3.314. The average of the nine semesters has been 3.235.

The 435 students belonging to classifiable groups taken together had for the entire time of their residence at the university an average scholastic grade of 2.934. To one familiar with our grading system this is a marked inferiority.

The seven classifiable groups had the following averages:

Chinese	3.35
Jews	3.18
Nordics	3.00
Foreign students, excluding Chinese	3.00
Alpines	2.94
Mediterraneans	2.83
Negroes	2.55

Only the Chinese equal the average for unclassified men.

The ten individuals among the 435 classified having the highest grades were:

A Nordic	4.94
A Chinaman	4.82
A Jew	4.73
A South African	4.68
A Nordic	4.68
A Nordic	4.65
A Chinaman	4.48
A Chinaman	4.47
A Jew	4.41
A Negro	4.29

The first six in the above list have grades entitling them to election to Phi Beta Kappa or Tau Beta Pi. No others of the 435 classified are clearly eligible to such election. Three per cent. of those classified as Nordic appear in the list of ten best students, 8.33 per cent. of the Chinese, 2.15 per cent. of the Jews, 1.57 per cent. of foreigners, excluding Chinese, 1.66 per cent. of the Negroes, no Alpine and no Mediterranean. In the case of the Mediterraneans, at least, the number involved is too small to have any significance.

In view of the alarms that have been sounded as to the degeneracy to be expected from hybridization, perhaps the most interesting of these facts is that the aggregate of 435 classifiable students, including thirty-six Chinese slightly superior to the average, should be so distinctly lower in scholastic standing than the unclassifiable mass. The hundred Nordics are decidedly below the average of unclassified students. So are the Jews.

The figures given are reported merely as a bit of evidence to be put with other evidence for what it may be worth.

THE PURPOSE AND PROGRESS OF OCEAN-SURVEYS[1]

By J. P. AULT

COMMANDER, YACHT *Carnegie*, CARNEGIE INSTITUTION OF WASHINGTON

THE oceans occupy so large a part of the earth's surface that knowledge of their contents and physical conditions is of prime importance. Especially is this true for certain problems relating to the physics of the earth as a whole—geophysics. Human life and its environment and the evolutionary processes in the living world are influenced in countless ways by the varying physical properties of the ocean.

In the geophysical sciences with which we are concerned to-night, terrestrial magnetism, terrestrial electricity, and oceanography, much information has been collected already, though systematic investigations are but fairly started and the vast extent of the oceans still leaves many unsolved problems.

Our knowledge of the origin of the earth's magnetic and electric field is still imperfect. The exact interrelation between these two fields is not known, and we are interested in securing more information regarding the close connections which seem to exist between variations in magnetism, atmospheric electricity, auroral displays, earth-currents and transmission of wireless waves. Observations over the comparatively undisturbed ocean areas will very materially aid in the discussion of all these phenomena.

The history of ocean magnetic surveys goes back to the time of Columbus, who is credited with the discovery of the magnetic variation or declination. This is the angle between the true or astronomic meridian and the magnetic meridian. As is well known, the magnetic compass does not point toward the geographic poles, but toward the magnetic poles of the earth, the north magnetic pole being located somewhere north of Hudson Bay and about 1,000 miles from the true pole.

The steps in the development of the compass from a loadstone floating on a piece of wood in a vessel of water to its present form are not fully recorded. It apparently was used by the Chinese for navigational purposes as early as the fourth or fifth century and by the Europeans as early as the twelfth century. To Columbus we trace the first distinct step in removing from vague superstition the real cause governing the directive action of the compass.

The dramatic and epoch-making events of Columbus's first voyage to America in 1492 have been repeated often, but their significance in the early history of the compass may excuse a recounting of some of the details at this time. When seven days out from the Canary Islands, Columbus wrote: "On this night the needles turned to the northwest, and in the morning they turned more northwest." Four days later he wrote: "The pilots marked the north and found that the needles had turned to the northwest a full point (11¼°). The mariners were alarmed and anxious but did not say why. The Admiral (Columbus) knew and ordered them to return to mark the north again in the morning and then the needles were found true. The cause is that the star (North) appears to make the movement and not the needles."

[1] Address delivered on November 22, 1927, at the Carnegie Institution of Washington, Washington, D. C.

Up to the time of Columbus it was thought that the compass pointed to the true north at all places. It was the common practice to mount the card on the needle in such a way that the compass showed true north for any one particular locality. If the compass was used in another locality, then the card was shifted the proper amount to again indicate true north. The difference was ascribed to an error inherent in the particular needle used. In this case Columbus, to quiet the fears of his company, undoubtedly shifted the card on the compass so that in the morning it indicated true north again.

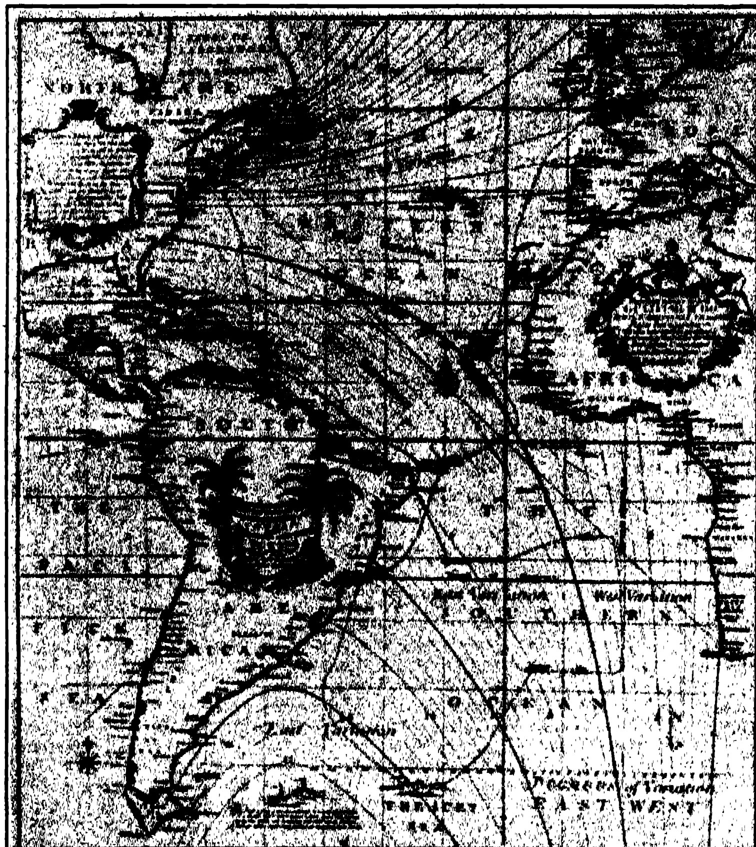
He had shifted the compass card on a previous voyage, for in 1460 when near Sardinia and an unruly ship's company wished him to take them to Marseilles for aid Columbus writes: "Being unable to force the crew's inclination I yielded to their wish and, having first changed the points of the compass, spread all sail, for it was evening and at daybreak we were within the Cape of Carthagena while all believed for a certainty that they were going to Marseilles." He also made a practice of entering in his log book the day's run as considerably less than the leagues actually sailed so as not to alarm his crew by the great distance back to Spain. These events shed an interesting light on the status of the men in sailing-ship crews in the early days. They were all adventurers together, and all seemed to know just where they were going and were aware of the compass course to be followed.

Columbus was a resourceful leader, and that he was an expert navigator with an excellent knowledge of sailing conditions in the North Atlantic is shown by the fact that the route he selected is exactly the same that would be selected to-day to make the same voyage. Before departure from the Canary Islands he changed the rig of one of his ships from fore-and-aft to square rig, showing that he knew he was to sail in the region of the "trades" with fair wind. During the remainder of the first voyage he makes no mention of the compass, apparently depending upon the same "movable" north star for his direction and guidance. However, during his third voyage he again records the fact that not long after leaving the Canary Islands the compass again turned to the northwest a full point, thus confirming the first discovery that the compass changes its pointing from place to place.

There is evidence that Columbus attempted during his return voyage to use this variation of the compass to help determine his position in longitude. Before the invention of accurate timepieces, navigation consisted in observations of the noon altitude of the sun for latitude and crude estimation of course and distance to determine longitude. This method was very unsatisfactory, since unknown ocean-currents and errors in reckoning made it impossible to keep accurate account of the ship's position. Edmund Halley, the noted astronomer, at one time was over 300 miles out of his reckoning on one of his famous voyages in 1698–1701.

Large prizes were offered for a more reliable method of determining longitude, and in 1698 Halley began his voyages in the Atlantic Ocean on the *Paramour Pink* to "improve the knowledge of the longitude and variations of the compass." As a result of these voyages he constructed and published the first magnetic chart of the oceans, and his method of drawing lines through points of equal declination is still used in nautical charts to-day. His map was used for many years, not to determine the longitude, the purpose for which it was constructed, but to give the navigator his compass correction as he sailed from port to port.

Halley used a very simple method to determine his compass variation, merely



HALLEY'S ATLANTIC CHART OF THE LINES OF EQUAL MAGNETIC DECLINATION AS BASED ON HIS OBSERVATIONS MADE DURING THE CRUISE OF THE "PARAMOUR PINK," 1698-1700.
[The dotted lines show the tracks followed by Halley's vessel.]

HALLEY'S ATLANTIC CHART.

taking the amplitude of the sun, *i.e.*, its compass bearing when on the true horizon, in the evening, and again in the morning, one half the difference between these two bearings being the compass variation at midnight. Over 200 years later we were able to add many values to the declinations which he observed by computing for him the results of his observations taken on the sun when that body was at some altitude above the horizon.

A comparison of the early maps showing the compass variation with our most recent ones will show the changes which have taken place in the 200 years between the voyages of Columbus and Halley and in the interval of 200 years to the present time. It is readily seen why Halley's scheme to determine longitude by means of a magnetic chart failed of its purpose because of the changes constantly taking place in the compass pointing. Halley himself knew of these changes and cautioned the users of his chart to take them into account.

To give some idea as to the amount of these changes, it might be noted that our two cruises in the Indian Ocean in 1911 and 1920 showed that the compass was

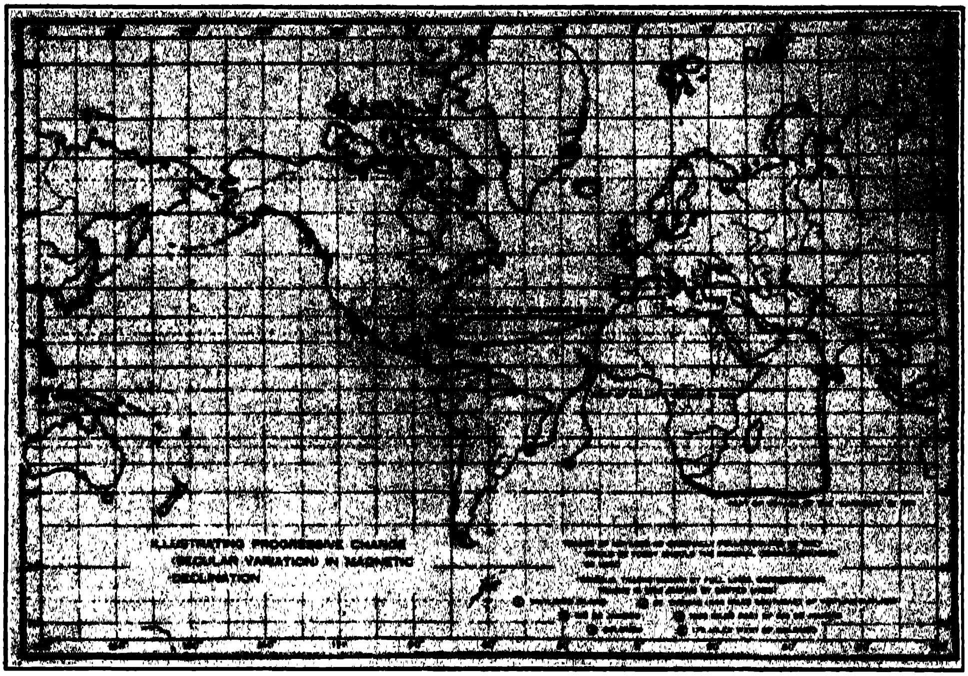
changing its direction over one third of a degree annually in the central part of the ocean. In 1911 the navigational charts for this ocean were in error by as much as one half point, chiefly owing to lack of accurate information as to the amount of the annual change. In 1580 the magnetic needle pointed 11° east of north at London and by 1812 it pointed 24° west of north, a change of 35° in 232 years. It now points only about 16° west of north. The causes of these changes and variations are not as yet known, and their explanation constitutes one of the chief problems in the science of terrestrial magnetism.

It is with these changes that we are chiefly concerned in a study of the earth as a magnet in trying to explain the origin of the earth's field, the causes of the changes which are observed during the day, the variation with the seasons during the year, and the secular or progressive change from year to year. We also wish to know why there is such close relation between changes in terrestrial magnetism known as magnetic storms and the occurrence of polar lights or auroras, both north and south, and changes in solar conditions, and why we have eleven-year periods in magnetic changes and disturbances coincident with the well-known eleven-year periods in sunspot activity.

Since we can not bring the earth into the laboratory and study its problems, we must go out over its surface, penetrate into its interior, into its atmosphere, and into the ocean depths as far as present inventive genius will permit, and observe and record the results of experiments which nature is performing on a cosmical scale.

In order to secure the data necessary for a complete study of these various problems in magnetism, it was decided early in the organization of the magnetic-survey work of the Carnegie Institution of Washington to extend the investigations to the large ocean-areas. Since the time of Halley in 1700, occasional magnetic observations have been made at sea incidentally on voyages of discovery and exploration, as those of the *Erebus* and *Terror*, the *Pagoda*, the *Challenger*, the *Discovery*, and the *Gauss*. But over 200 years elapsed after Halley's survey before another expedition started out primarily to make magnetic observations at sea. The *Galilee* sailed out of the Golden Gate in 1905 to survey the Pacific Ocean, making three cruises during the period August, 1905, to June, 1908. On these expeditions, the fruition largely of the plans and vision of Bauer and his colleagues, observations were made not only to determine the magnetic declination but also the magnetic dip or inclination and the strength of the earth's magnetic field. The instruments used in these observations were mounted on an open bridge exposed to wind and weather, and many doubted whether worth-while observations could be made at sea with equipment then in use.

The accuracy of the results with these more or less experimental instruments and the promise of increased accuracy with new devices invented and constructed by Peters and Fleming indicated the desirability of continuing the ocean-survey. At the same time the effect of what little iron was present in the hull of the *Galilee* was so difficult to control and measure in the results that it was decided to construct a specially designed nonmagnetic vessel. In 1909 the *Carnegie* was completed and began her long series of cruises in August of that year. Reference to the map will show the extent of these cruises for the period 1905 to 1921; 3,316 declination and 2,147 inclination and horizontal intensity stations were occupied. Improvements in the instrumental equipment increased materially both the amount and the accuracy of the data secured. Since advancement and success of ocean-surveys are measured by progress in the development of instru-



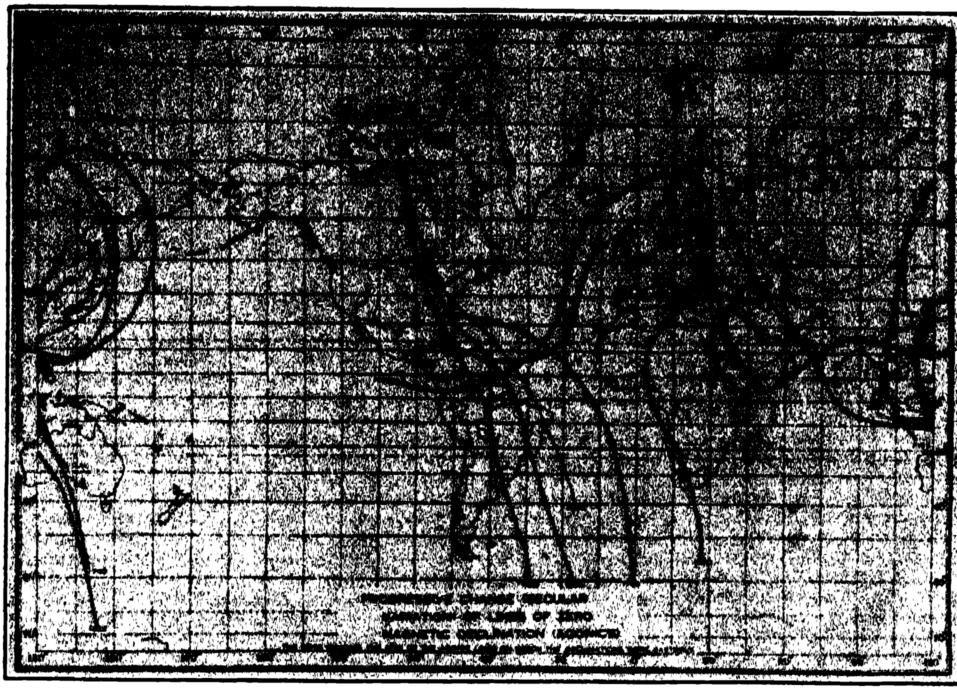
PROGRESSIVE CHANGE (SECULAR VARIATION) IN MAGNETIC DECLINATION.

mental equipment, full credit must be given to those who have developed this phase of the ocean-surveys executed on the *Galilee* and the *Carnegie*.

A very satisfactory distribution of stations has been accomplished, and the accuracy of present-day magnetic charts used by navigators has steadily increased since the various hydrographic offices began using the data resulting from these surveys.

At only about eighty stations do we have cruise-intersections where reliable information has been obtained regarding the changes which have taken place over a period of years, the so-called secular variation. To improve this condition, in future ocean-survey work it is planned to retrace previous cruises and reoccupy as many points as possible in order to secure the maximum data on the amount and direction of this secular variation. This will furnish valuable information for keeping navigation charts up to date as well as supplying the necessary data for the advancement of theoretical studies and investigations.

The study of the earth's electric field, that is, of terrestrial electricity and including both atmospheric electricity and earth-currents, is now being carried forward side by side with the study of the earth's magnetism. The importance of these investigations has increased in recent years because of the close relation between variations in atmospheric-electric and earth-current phenomena and variations in magnetic conditions. Recent theories regarding the nature of electricity and the constitution of matter and the rapid advances made in radio transmission have given added stimulus to the study of the earth's electric field. The sun is included in this study because of the close connection between magnetic and atmospheric-electric phenomena and solar activity, and cooperative work with the Mt. Wilson Solar Observatory in these investigations was started last year.

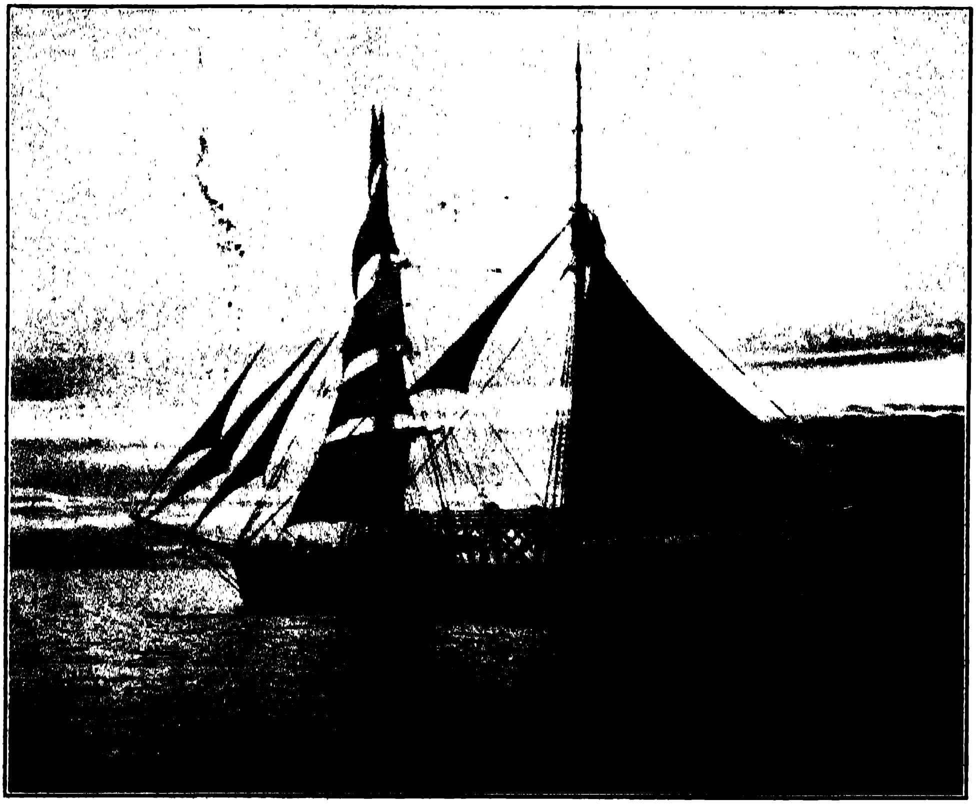


PROGRESSIVE CHANGE (SECULAR VARIATION) OF LINES OF ZERO MAGNETIC DECLINATION (AGONICS).

Some experimental observations in atmospheric electricity were made in 1908 on the *Galilee* and in 1909 to 1914 on the *Carnegie*, but it was not until 1915 that a systematic and definite program of observations was undertaken with new and improved methods and instruments devised and constructed chiefly by Swann and Fleming. A well-known European student of atmospheric electricity states that the only new contribution to this science within the past ten years was that resulting from the cruises of the *Carnegie*, which is especially valuable because of the wide distribution of information obtained.

The electric elements which have been investigated include potential gradient, both positive and negative ionic content, conductivity, and ionic mobility, penetrating radiation, and radioactive content of the air. The potential or electric charge in the air increases with height above the earth's surface, being about 100 volts at the height of one meter. This is the so-called potential gradient and is measured by noting the deflection on the fibers of an electrometer while the collector is raised one meter. There are present in the air at all times both positively and negatively charged particles called ions, about 1,000 of each kind in a cubic centimeter of air, and with our instruments it is possible to count the number with fair accuracy. Intimately connected with the number of ions in the air is the electric conductivity, or its ability to carry an electric current. Air is forced past a charged conductor at a uniform rate of speed, and the rate of discharge is noted by the changing position of the fibers in an electrometer.

Whether penetrating radiation or "cosmic rays" coming into the earth's atmosphere from outer space can be one of the causes of the ionization of the air is one of the problems being investigated, and observations are made at sea to determine the amount and variation of this radiation by observing the rate of



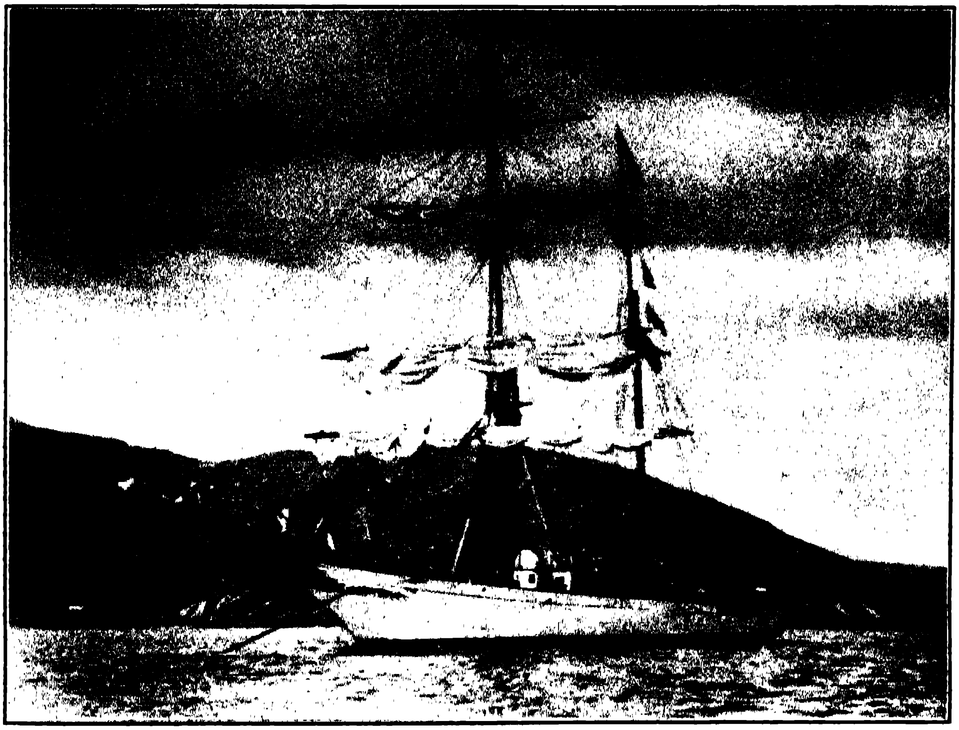
THE *Galilee*. (DURING THREE CRUISES IN THE PACIFIC OCEAN, 1905–1908, THIS VESSEL COVERED OVER 73,000 MILES.)

ionization in a closed copper vessel. The radioactive-content observations are arranged to collect and measure the amount of radioactive material, such as radium and thorium, present in our atmosphere, this being another source of ionization.

Under the action of the earth's electric field, positive ions are traveling toward the earth and negative ions are traveling upward into the air, giving rise to an air-earth electric current. The rate at which this interchange takes place would neutralize the earth's negative charge in a very short time were there no recharging source of energy. Various theories have been advanced to account for the source of this supply, *e.g.*, lightning, the sun, but the problem still awaits solution.

Conditions at sea are much more favorable for investigating the earth's electric field than on land, where dust and smoke in the air and presence of changing cultural or permanent topographic features such as trees, buildings or contours cloak the true characteristics of the atmospheric-electric phenomena. To further improve the atmospheric-electric results and to note the conditions at sea, dust-count observations are to be included in the program since it is known that the presence of dust in the air has a marked influence upon atmospheric-electric conditions.

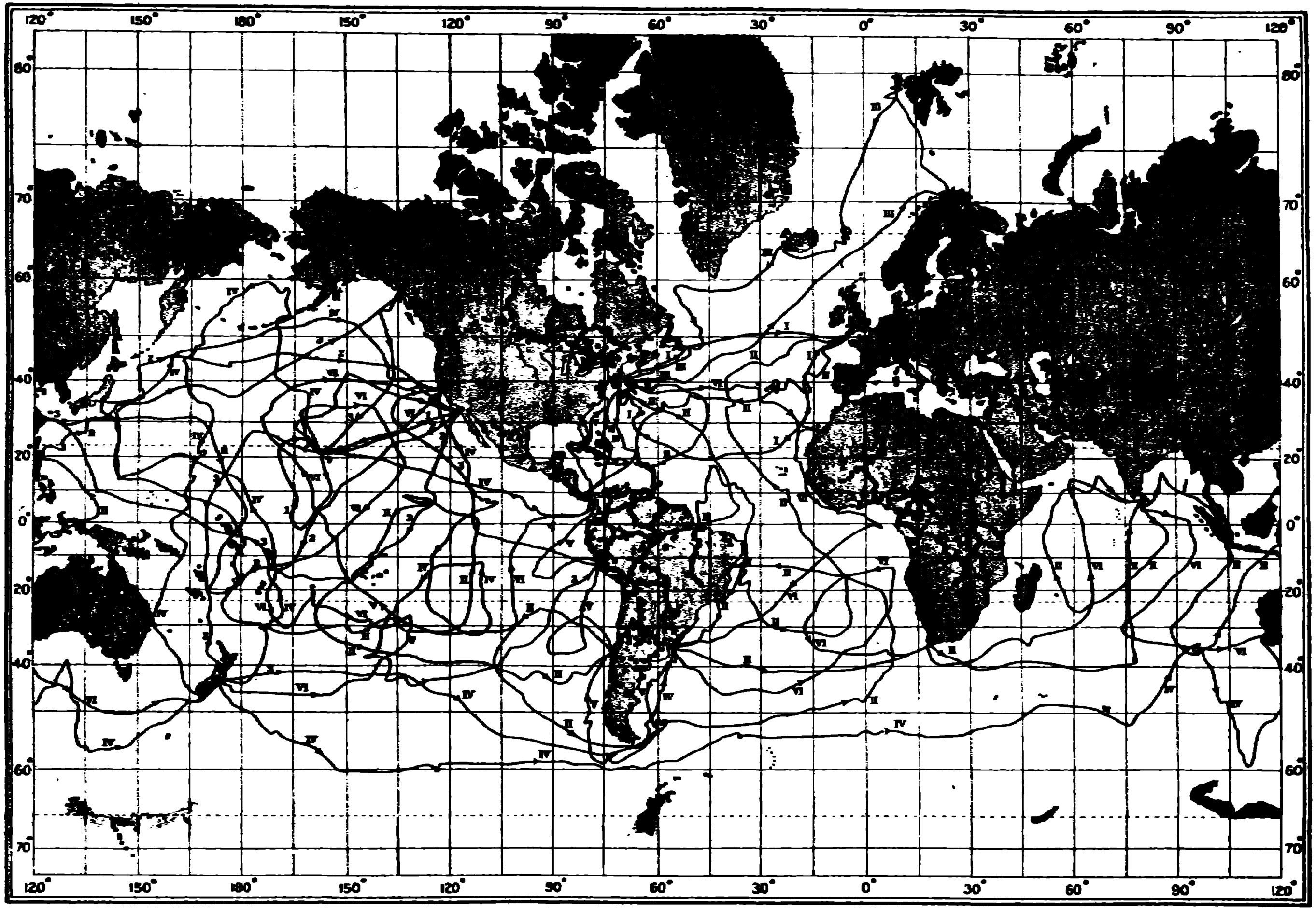
In order to determine the variations which take place in the earth's electric field during a twenty-four-hour period, continuous observations of the changes in these elements are carried out on the



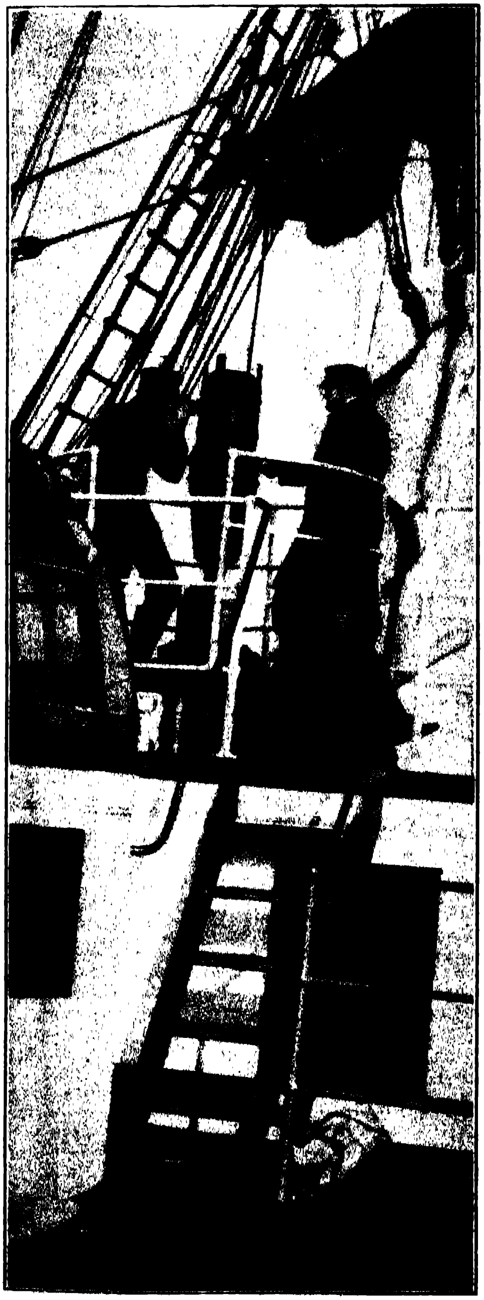
NONMAGNETIC YACHT *Carnegie* OFF PORT LYTTELTON. (DURING SIX CRUISES IN ALL OCEANS, 1909–1921, THIS VESSEL COVERED OVER 291,000 MILES.)

Carnegie at frequent intervals. I will but mention the difficulties of carrying out such observations under conditions which persist at sea, insulation troubles due to condensation and to salt spray, and difficulties attending the use of instruments on a rolling ship. In dealing with insulation difficulties we have learned that our favorite slogan "Electricity never fails" has always held true. The instrument will always work if the insulation surfaces are clean and all connections are good.

A discussion by Mauchly of these twenty-four-hour series of atmospheric-electric observations at sea on the *Carnegie* disclosed that the chief maximum of the diurnal variation of the potential gradient occurs at about 18^h Greenwich mean time all over the world, approximately the time when the sun is in the meridian of the north magnetic pole. This conclusion was confirmed by Sverdrup during Amundsen's Arctic-Drift Expedition on the *Maud.* The true physical explanation of this discovery is not yet apparent. Wait and Sverdrup point out that the rotating magnetic field of the earth induces electromotive forces in the earth's electric field, the variations of which are in remarkable agreement with the observed variations of the potential gradient over the oceans. This agreement appears too good to be accidental, but further evidence is needed for a satisfactory physical interpretation. To add to the information regarding variations of the potential gradient, an automatic photographic recording electrometer is to be mounted near the truck of the mainmast during the next cruise. Some experi-



MAGNETIC-SURVEY WORK OF THE DEPARTMENT OF TERRESTRIAL MAGNETISM DURING THE PERIOD 1905–1926. (CRUISES OF THE *Galilee* ARE INDICATED BY ARABIC NUMERALS, THOSE OF THE *Carnegie* BY ROMAN NUMERALS; BLACK DOTS SHOW THE LAND STATIONS.)



OBSERVING MAGNETIC DECLINATION WITH COLLIMATING-COMPASS ON BRIDGE OF *Carnegie.*

mental work with this apparatus was done during the return of the *Carnegie* from New York to Washington last month by W. C. Parkinson, who will have charge of the atmospheric-electric work during the next cruise.

The important contributions to the study of various geophysical problems which are being made by investigations of the Kennelly-Heaviside conducting layer and of radio transmission and variations with changing magnetic and electric conditions greatly enhance the value of the ocean atmospheric-electric data and indicate cooperative investigations along similar lines for future ocean-work. It is planned to begin at sea investigations of the conducting layer and to carry out experiments on the variations of signal-intensity, following methods already in use on land.

Important correlations between earth-current variations and changes in other geophysical and cosmical phenomena, such as solar activity, magnetic disturbances, and polar lights, have resulted from an investigation of observatory records, and the importance of these studies in the general study of the earth's magnetic and electric fields now warrants beginning systematic earth-current observations at sea. Some preliminary experimental work was done while the *Carnegie* was *en route* from New York to Washington this year in order to determine best methods and instruments for such investigations over the oceans.

The challenge of the vast, practically unknown expanse of the atmosphere above the earth's surface and of the equally unexplored depths of the ocean awaits the pioneering spirit of a Langley or the ingenuity of a Lord Kelvin to penetrate their mysteries. When inventive genius makes it possible to investigate the modifications in magnetic and electric variations due to change in alti-

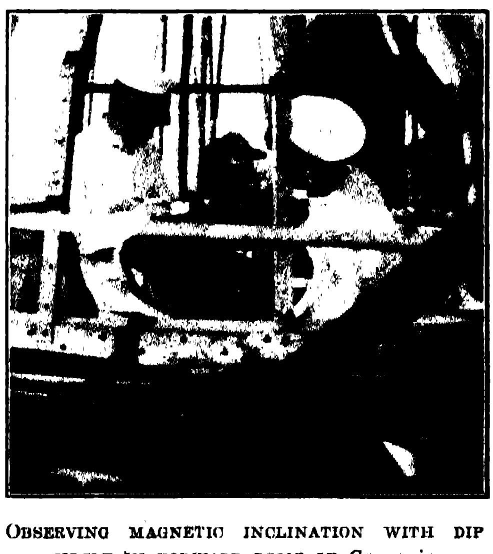
OBSERVING MAGNETIC DECLINATION WITH DEFLECTOR-COMPASS IN AFTER DOME OF *Carnegie.*

tude, many new and important discoveries will be made.

The mysteries of the ocean-depths, however, are slowly being unfolded through advances in the growing science of oceanography. This science has been defined as "comprehending the investigations which deal with the form and divisions of all the marine areas on the surface of the globe, the winds that blow over the surface waters, the contours of the ocean-bed from sea-level down to the greatest depths, the temperature, the circulation, the physical and chemical properties of sea-water, the currents, tides, and waves, the composition and distribution of marine deposits, the nature and distribution of marine organisms at the surface, in the intermediate waters, and on the floor of the ocean, as well as the modifications brought about in living things by the conditions of their existence, the relation of man to the ocean in the development of commerce, fisheries, navigation, hydrography, and marine meteorology. All this vast assemblage of knowledge, which embraces some aspects of astronomy, geography, geology, physics, chemistry, and the biological sciences, makes up the modern science of oceanography."

Up to the time of the *Challenger* expedition in 1872 to 1876, oceanographic research had been limited to restricted areas, or was incidental to some exploratory expedition, or was associated with some national fisheries investigations. Following the stimulus given by the *Challenger* results, oceanographic investigations were much extended, and new methods and instruments were devised. However, the vastness of the regions to be explored and the time and expense entailed in sending instruments to the bottom of the ocean-deeps leaves many unsolved problems for the oceanographer. Time does not permit more than a brief mention of the pioneer work done by Forbes, Thomson, Agassiz, Murray and others who laid the foundations of the present science of oceanography.

In spite of all the vast amount of data that has been collected, we have only a general idea of the contours of the ocean-



OBSERVING MAGNETIC INCLINATION WITH DIP CIRCLE IN FORWARD DOME OF *Carnegie.*

OBSERVING ELECTRIC POTENTIAL-GRADIENT WITH SPECIAL COLLECTOR AND ELECTROMETER AT STERN OF *Carnegie*.

bed and only a meager knowledge of the bottom sedimentary deposits which are of peculiar interest to the geologist in his study of the age and formation of the earth and the changes which time has witnessed. The mapping of the configuration of the oceanic basins covering over two thirds of the earth's surface should be as important as the mapping of the land masses which occupy less than one third. Such information is necessary for the geodesist in his study of the movements within the earth's crust and for the seismologist in his study of the origin, history and probable future development of submarine earthquakes.

The movements of vast bodies of water relatively to one another and to the land due to winds and tide and the vertical movements due to changes of temperature and salinity make the ocean with its vast capacity for carrying heat a powerful factor in its influence upon practically every phase of life upon the earth, in its control of climate, and in its determining effect upon man's migration and habitation.

Perhaps the most fascinating study connected with the sea is the multitudinous life found in all oceanic waters from the surface down to the deepest abyss yet explored. Physical changes in the ocean-waters have profound influ-

ences upon marine life, its variety, its amount, and its distribution. A knowledge of these influences will contribute in many ways not only to the study of evolutionary processes taking place in the sea but to the practical problem of economic use of the ocean's food resources.

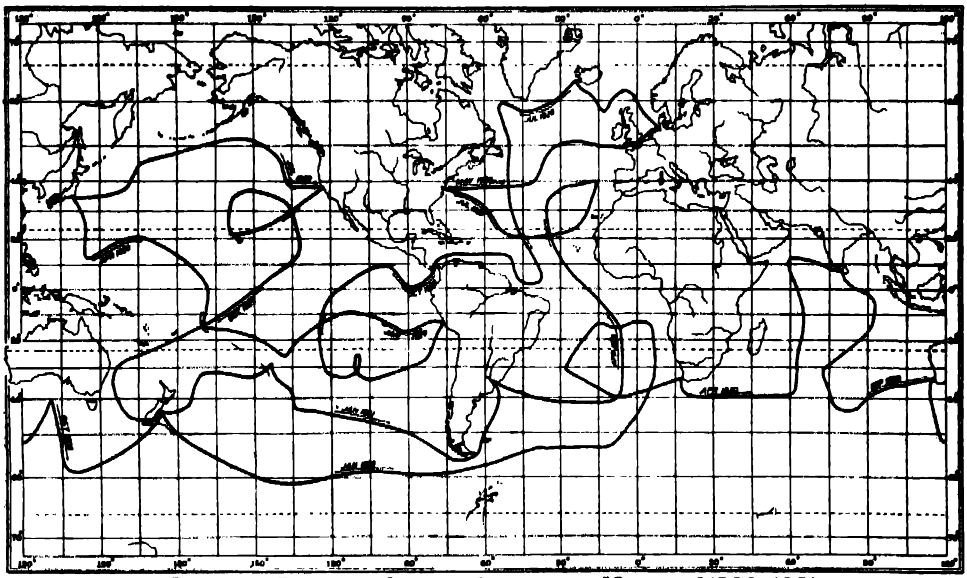
Many problems of oceanography are of interest to the Carnegie Institution of Washington through the activities of its various departments and research associates. The vast extent of the ocean-areas to be covered by the next cruise of the *Carnegie* offers unique opportunity to add new and much-needed information in this science from regions never investigated.

To carry out the proposed increased program of general oceanographic work has required many structural changes on the *Carnegie*. During the past summer the vessel was in Hoboken, New Jersey, undergoing repairs and alterations. A new stateroom was added in the cabin since the technical staff is to be increased to seven, the additional man to be especially trained in chemistry and marine biology. The two lifeboats were moved from the quarter-deck to overhead platforms amidships opposite the after dome, leaving the quarter-deck free for the operation of the bronze winch, sounding wire, and special davits for handling tow-nets, water-bottles, deep-sea reversing thermometers and bottom-samplers.

Two new laboratories were constructed on deck; one will be specially fitted for physical oceanographic, biological and chemical work, and the other will house the radio and echo-sounding equipment.

In physical oceanography it is planned to obtain temperatures and water samples at depths of 5, 25, 50, 75, 100, 200, 300, 400, 500, 700, 1,000, 1,500, and 2,000 meters every 150 to 200 miles, with occasional series down to the bottom with a limit at 20,000 feet. To obtain a continuous record of surface-temperatures, a distant-recording thermograph has been installed with its bulb on the hull about seven feet below the water-line and with its recorder in the new laboratory. These records will be checked occasionally by the usual method, direct readings with draw-bucket and thermometer.

ATMOSPHERIC-ELECTRIC INSTRUMENTS IN OBSERVATORY ON *Carnegie*. (LEFT TO RIGHT, ION COUNTER, PENETRATING-RADIATION APPARATUS, AND RADIOACTIVE-CONTENT APPARATUS; THESE INSTRUMENTS ARE SUSPENDED IN GIMBALS SUPPORTED FROM OVERHEAD.)

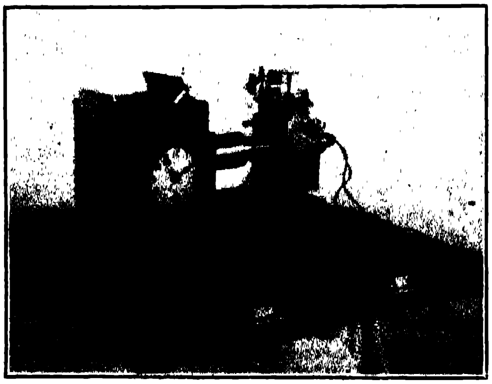


TENTATIVE ROUTE FOR SEVENTH CRUISE OF THE "CARNEGIE," 1928–1931

Water samples and temperatures will be secured by Nansen water-bottles and Richter reversing deep-sea thermometers, using a series of ten on the wire at one time. The water-bottle has a capacity of 1¼ liters, and two thermometers will be used with each one in order to check the temperature. The salinity and density of each water-sample will be determined on board ship by the Wenner electric conductivity method and checked occasionally by the silver-nitrate titration method. The water-sample also will be analyzed chemically for oxygen, nitrate and phosphate content, and hydrogen-ion concentration.

Samples of muds and sediments from the bottom will be secured by use of the snapper-type of sampler, as modified by Vaughan, and a larger Eckman tube-sampler, as modified by Trask for deep water. It is now known that bottom-living creatures feed on organic matter found in bottom muds, and that these muds are often teeming with life. From a study of these organisms and fossil remains, together with borings from oil-wells, important conclusions have been reached regarding the origin of oil-producing deposits. The Geophysical Laboratory also is interested in the nature and derivation of inorganic marine deposits in the study of the age of the earth and the various processes of its formation.

The machinery necessary to handle water-bottles, thermometers and bottom-samplers has been installed on the *Carnegie*. It consists of a 30-H. P. gasoline engine and a 12-KW generator installed below decks in the engine-room to furnish the required electric power A bronze winch weighing three tons, operated by a 15-H.P. electric motor, has been installed on deck. Two reels and two gypsy-heads are provided, one reel containing 20,210 feet of special aluminum-bronze stranded wire rope, 3/16-inch or 4 mm. in diameter, and the other containing 6,808 feet of ¼-inch or 6-mm. wire. This wire was made in Germany and was designed especially for oceanographic work after extensive tests and experiments by those in charge of preparations for the German Expedition on the *Meteor*, 1925 to 1927.



AUTOMATIC PHOTOGRAPHIC-RECORDING ELECTRIC POTENTIAL-GRADIENT RECORDER TO BE MOUNTED NEAR THE TRUCK ON TOP OF MAINMAST OF *Carnegie*.

The gypsy-heads are to be used in handling yards, sails, hoisting lifeboats, hauling in earth-current cables, and for the general work on deck. Special bronze davits and blocks have been installed for handling the wire as it is played out or hauled in. Platforms have been constructed on both port and starboard sides, where the observer will stand while attaching or detaching the water-bottles and thermometers to the sounding wire.

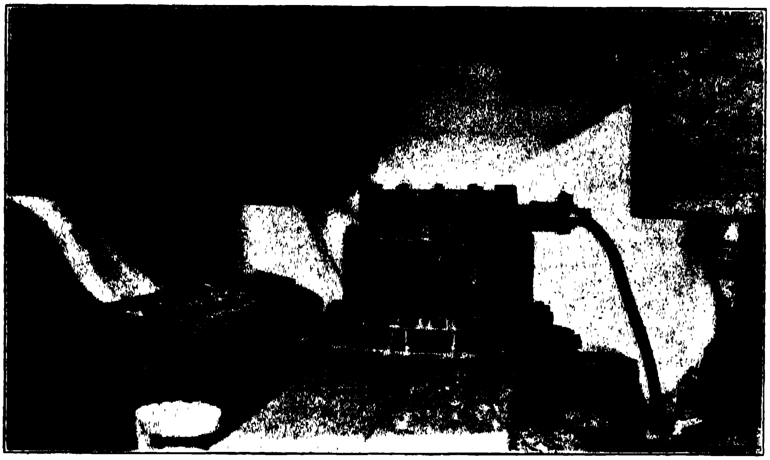
The winch has been constructed so that the reels may be operated either singly or together, thus allowing one wire to be played out on the brake while the other wire is being hauled in. This will allow two series of water-bottles to be operated simultaneously, thus saving materially in the time required at each station.

It is planned to heave to every other afternoon, taking in all sails except those required to keep the vessel as nearly stationary as possible. To keep the wire vertical or nearly so will require skilful maneuvering, and it may be necessary to use the main engine occasionally to accomplish this result. Helland-Hansen and Nansen have carried out similar work with great success on the *Armauer Hansen*, a sailing vessel of only one half the size of the *Carnegie*. They state that[2] "owing to its special construction the ship is easily maneuvered in such a manner that the line along which the oceanographic instruments are suspended remains in a vertical position throughout the time of observation even if there is a strong drift caused by wind or current." This is essential in order to obtain correct depths by wire measurements.

As a further aid in checking the depths at which temperatures and water-samples are obtained, simultaneous use is to be made of protected and unprotected thermometers, calibrated for pressure-effects, placed at frequent intervals as the wire is lowered into the water. The difference between the readings of the two thermometers at any level will give the depth for that level. This method was used recently with success by the German Atlantic Expedition on the *Meteor*. To avoid rapid and excessive drift of the vessel when hove to in a strong breeze, sea-anchors will be used to check the headway. Simultaneous determinations of depths with actual wire soundings and with the echo-method, together with temperature and salinity data at all levels, will give information of great value in establishing proper formulae for the velocity of sound in sea-water in the deep basins of the ocean.

The latest type of sonic depth-finder as developed by Harvey C. Hayes has been installed on board the *Carnegie*, and frequent determinations of ocean-depths will be made as the vessel is proceeding on her way. The depth can be determined in a very few moments, the method consisting essentially of measuring very accurately the time-interval between a signal sent out from the ship and the return of the echo from the bottom of the sea. The United States Navy

[2] Helland-Hansen and Fridtjof Nansen, The Eastern North Atlantic, Geofysiske Publikasjoner, 4; (2) 3–4 (1926).



OSCILLATOR BEING INSTALLED IN KEEL OF *Carnegie* FOR TRANSMITTING SIGNALS IN MEASURING OCEANIC DEPTHS BY THE ECHO-SOUNDING METHOD.

is cooperating in this work by lending the necessary equipment consisting of an oscillator for transmitting the signal, six microphones for receiving the echo, and a depth-finder for measuring accurately the interval between signal and echo. The method is accurate to within about ± 5 fathoms or 30 feet for depths greater than 100 fathoms, the range over which the sonic depth-finder is designed to operate.

In marine biology it is planned to confine attention to microbiology, to determine the abundance and distribution of plankton and other microscopic organisms. Shallow-water dredging for diatoms and foraminifera will be undertaken also in cooperation with Dr. Albert Mann, a research associate of the Carnegie Institution of Washington. Quantitative distribution of plankton at various depths from the surface down to 100 meters will be determined by the examination of definite quantities of water brought up by means of special water-bottles, or by use of a hose let down to depths found practicable.

Some study will be made also of surface plankton by straining a continuous stream of water through a fine-meshed net. Marine organisms also will be secured by tow-nets, and hauls both vertical and horizontal are to be made from the surface down to a depth of 150 to 200 meters. A special boom-walk has been rigged in connection with the vessel's boat-boom, where the observer can walk out thirty feet from the ship's side in fair weather, dip up any marine life from the surface, or operate the tow-nets well out from the disturbing influence of the vessel and its motion through the water.

To assist the biologist in his study of marine life in its native habitat at the bottom of the ocean, a diving helmet has been secured for use in shallow-water. This device has been used by amateurs at depths of thirty feet and can be used safely at depths of fifty to one hundred feet.

Equipment will be carried also for securing specimens of dolphins and porpoises from regions where no specimens have been secured heretofore. Such specimens are of special interest to Remington Kellogg, a research associate of the Carnegie Institution of Washington, in his study of the evolution of the whale and other marine vertebrates.

Limited space on the vessel and time and restrictions as to power and machin-

ery prohibit undertaking any deep-sea trawling or dredging. This work may be taken up during a later cruise, when it is hoped that chief attention may be devoted to work in oceanography.

Any program of oceanographic investigations should include extensive work in marine meteorology in view of the important influence upon climate of mass movements of large bodies of heat-bearing oceanic waters. The study of the physical interchange between the surface of the ocean and the air above it is important in the study of atmospheric circulation and disturbance over the entire surface of the earth because of the fairly normal conditions which exist at sea.

The foundations of the science of marine meteorology were laid by an American, Admiral Matthew Fontaine Maury. His book "Physical Geography of the Sea" is still a classic, although some of his theories and conclusions have been supplanted. Due to his efforts an international conference was held at Brussels in 1853, and a general program for marine meteorological observations was adopted. Maury introduced sailing directions and pilot charts which were of untold value to shipping interests, especially in the time of sailing ships. Monthly pilot charts of the great oceans are now issued in advance by the Hydrographic Office and the British Admiralty and constitute a most important aid to navigation.

While conditions at sea are fairly normal for the study of the atmosphere, yet the ocean is only a highway and the observer is always on the move from place to place. Instruments must be especially adapted for use on moving and rolling platforms, and progress in marine meteorology, as in other oceanographic investigations, has developed only as rapidly as the invention and utilization of the proper instrumental equipment has permitted.

To study the physical interchange of heat and moisture between the ocean and the atmosphere, it is planned to observe the temperature and humidity lapse-rates from sea-level to masthead. Accompanying observations of wind direction and velocity and of changes in atmospheric pressure will be made.

Variations in the amount of solar radiation received at the earth's surface and their influence upon world-wide weather conditions have been the subject of much study in recent years by Abbot and Clayton. It has been thought worth while to include such observations in our meteorological program, together with observations of cloud systems, rainfall, evaporation, and dust-content and carbonic-acid content of the atmosphere. Increased data of these kinds over the great oceanic areas to be covered by the next cruise of the *Carnegie* may be extremely valuable in the comparison of world weather with solar variation, in the determination of the rate at which the atmosphere is being charged with water vapor so vital to life on the continents, and in the study of the dynamics of atmospheric circulation over the oceans.

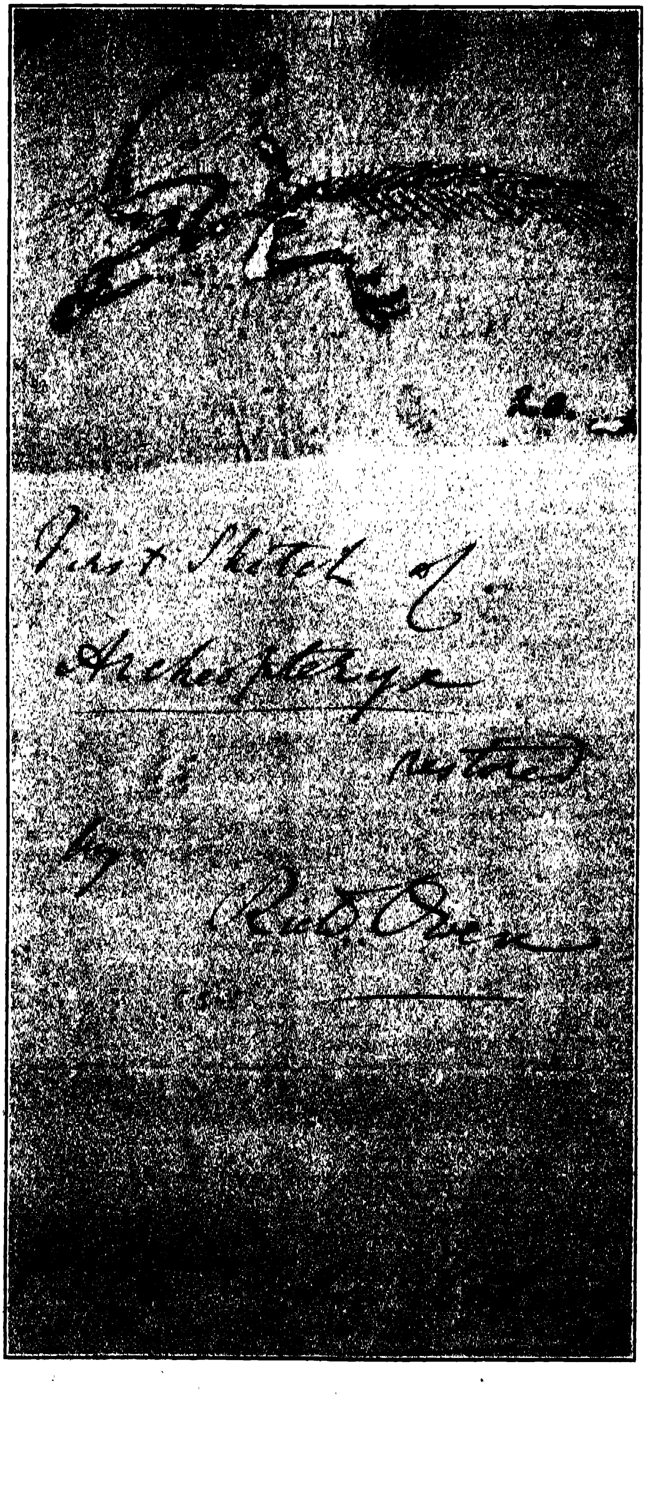
It is planned to compute at sea and publish promptly as the cruise progresses the pertinent oceanographic data for use of students and investigators of oceanography, as has been done heretofore in terrestrial magnetism. The physical data to be published include the following results of observations and calculations at various depths: Temperature, salinity, density observed and corrected for compression, oxygen-content, hydrogen-ion concentration, specific volume, and dynamic pressure and depth. A part of the water-samples will be tested for salinity and for gas-content, and a part will be stored below decks for later study in various laboratories. Biological specimens will be studied, sketched and preserved for transmission to some museum.

The dynamic calculations will be made in accordance with the method devised by Bjerknes and as modified by Hesselberg, Sverdrup and others. The dynamic conditions in the ocean may be viewed in the same light as similar conditions in the air. Winds blow obliquely from areas of high pressure towards areas of low pressure, taking into account the effect of the rotation of the earth. The force or velocity is proportional to the gradient or difference in pressure. So in the ocean, data as to temperature and density at two points at the same level permit us to calculate the difference in dynamic pressure between the two points. This is one of the factors which cause circulation, and the direction of this circulation also is affected by the rotation of the earth.

In the biological and chemical work, chief emphasis will be placed upon the collection of data and specimens. Some analysis of water-samples and study of specimens must be done on board ship immediately after collection, and as complete a preliminary examination and report as possible of the results of these investigations will be made as the cruise progresses. Interested organizations will be furnished with water-samples, bottom-samples and biological specimens for further study and report, and a final discussion and publication of the results of the cruise will be made by the institution at the conclusion of the work.

The Carnegie Institution of Washington is indebted to the following institutions and organizations for cooperation by lending special equipment or by giving expert advice in planning the program of investigations: The United States Navy Department, the National Museum, the Weather Bureau and the Coast and Geodetic Survey; the Scripps Institution of Oceanography of the University of California; the Museum of Comparative Zoology of Harvard University; the School of Geography of Clark University; the Geophysical Institute, Bergen, Norway; the Marine Biological Association of the United Kingdom, Plymouth, England; the German Atlantic Expedition of the *Meteor;* and the Carlsberg Laboratorium, Copenhagen, Denmark.

In this outline of the purpose and progress of ocean-surveys it is possible to present only a few of the outstanding developments and to sketch only briefly the problems as yet unsolved. The chief advances in surveys already made have come from invention of instruments capable of revealing the variations in natural phenomena in regions hitherto inaccessible. Thus the pathway to further progress in these branches of geophysics is made plain, and man's inventive genius is challenged in no uncertain terms.


First Sketch of
Archeopteryx
by
Rich. Owen

THE EARLIEST RESTORATION OF ARCHAEOPTERYX

By Dr. HERBERT FRIEDMANN

AMHERST COLLEGE

In this age of popularization of science by methods of visual education most of the more remarkable and noteworthy fossil animals have had the peace of their age-long slumbers rudely disturbed by the modern scientific artists, who, working under the direction of the paleontologists, with something of the aim, but not the methods, of the equally modern beauty-specialists, have attempted to restore flesh to sunken cheeks, to instil the luster of eager eyes in hollow sockets, to impart the appearance of life and vitality in frames so old and decrepit as to be utterly unable to bear the weight of their new rotund habiliments of flesh and muscle.

Archaeopteryx has been the subject of a greater number and variety of restorations than have most fossil types, and the dissimilarities in the various restorations are probably due to differences in the knowledge, acumen and imagination of their respective designers. However, it is quite certain that each prospective restorer is influenced to some extent by the attempts of his predecessors, and works either to emphasize their errors by contrast with his own accuracy, or to modify their lines and proportions in accordance with new-found facts and more recent theories. Consequently it is interesting to examine the very first attempt at a restoration of this famous bird, inasmuch as it is probably the only one that is wholly original, based on only one man's observations, and uninfluenced by the concepts and imaginations of previous workers.

The museum of the biological laboratory at Amherst College is fortunate in possessing the original sketch of Archaeopteryx drawn in Sir Richard Owen's own hand and labeled by him "First Sketch of Archaeopteryx Restored." It was given by Owen to Professor Hitchcock, then professor of natural history in Amherst College, and has since been deposited in the college museum where it now is. This drawing has never been published and is, as may easily be seen from the photography, only a rough, unfinished sketch.[1] The drawing is in ink on a piece of very thin paper which is pasted on the heavier paper on which the writing appears. The ink and the paper are both somewhat brown with age, but the lines are very clear and distinct. The boldness of the outlines indicate that the mental image Owen had of the creature was definite and sure. Of all parts indicated by him in this sketch the bill has been changed the most by more recent restorers, while the free digital claws in the wing have also been made more prominent by his successors. It is curious to note his spelling of the generic name of the animal, and to find that in his earliest attempt at restoring it he used the name presently held and not the name *Griphornis* which he had coined for it. Whatever its merits and demerits may be as judged by the more recent restorations based on fuller and more accurate knowledge of the structure of the animal, it is certain that merely as a restoration (in the sense of bringing a dead animal to life again) it is more successful than many of its more ambitious successors.

[1] In the reproduction the length has been reduced from 8½ to 7½ inches.

more satisfies me, & the conclusion which I continually stand to is that "there is a great suggestion for many years work." —

Your last work must have cost you very much labour & therefore I infer that you are strong & well. — I can assure you that I have by no means forgotten my short & very pleasant interview with you.

Believe me, my dear Sir,
yours sincerely
Ch. Darwin

DARWIN ON SPENCER

By BERNHARD J. STERN
NEW YORK, N. Y.

THE recognition of the significance of Darwin's "Origin of Species" was due primarily to the militant, propagandistic zeal of Thomas Huxley and Herbert Spencer, who for a period were almost alone in their advocacy of the theory of evolution. One would suspect, therefore, that Darwin, cognizant of the service Spencer had rendered, was appreciative and was kindly disposed toward Spencer's writings. Yet his reactions toward Spencer's work, as revealed in his letters, are variable, oscillating from extreme unbounded praise to sharp critical appraisement. One discerns in his disparaging letters the incompatibility of the approach of the two men: Darwin, the inductive scientist, cautious of generalizations, the patient gatherer of data; Spencer, the dialectician, the master of striking deductive generalizations.

As early as 1866, Darwin, after reading Spencer's "Principles of Biology," wrote of J. D. Hooker: "I feel rather mean when I read him; I could bear and rather enjoy feeling that he was twice as ingenious and clever as myself, but when I feel that he is about a dozen times my superior, even in the master art of wriggling, I feel aggrieved. If he had trained himself to observe more, even if at the expense, by the law of balancement, of some loss of thinking power, he would have been a wonderful man."

In his letter to E. Ray Lankester in 1870, he commends him on his appreciation of Spencer and concludes: "I suspect that hereafter he will be looked at as by far the greatest living philosopher in England; perhaps equal to any that ever lived." In the same effusive strain he wrote in his letter to Herbert Spencer, in 1872, after congratulating him on a polemical article on evolution which had appeared in the *Contemporary Review:* "Every one with eyes to see and ears to hear (the number, I fear, are not many) ought to bow their knee to you, and I for one do."

A decidedly opposite reaction is that revealed in his letter to John Fiske, in 1874: " . . . With the exception of special points I did not even understand H. Spencer's general doctrine; for his style is too hard for me."

That this letter to Fiske does not merely display a passing mood is shown by a hitherto unpublished letter of Darwin to Lewis H. Morgan, the American anthropologist, author of "Ancient Society." The letter, found in one of Morgan's scrap-books loaned to the writer by the library of the University of Rochester, is dated Down, Beckenham, Kent, July 9, 1877. It is here given *in toto:*

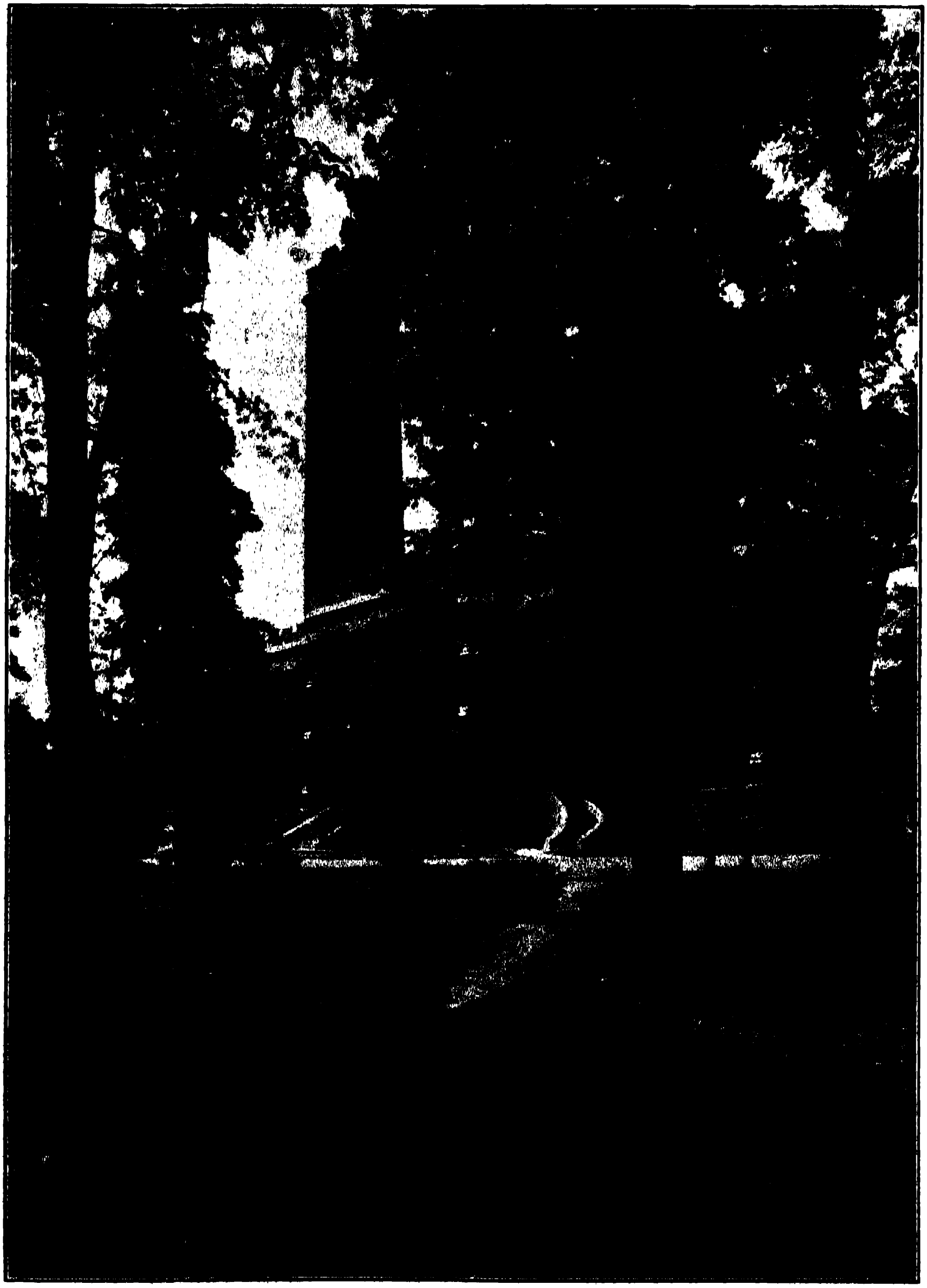
I thank you kindly for your very kind, long and interesting letter. I write in fact merely to thank you, for I have nothing else to say. I have lately been working so hard on plants, that I have not had time yet to glance at H. Spencer's recent work, and hardly to do more than glance at your last work. But I hope before very long to find more time. It is, however, a great misfortune for me that reading now tires me more than writing,—that is, if the subject sets me thinking. I am as great an admirer as any man can be of H. Spencer's genius; but his deductive style of putting almost everything never satisfies me, and the conclusion which I eventually draw is that "here is a grand suggestion for many years' work."

Your last work must have cost you very much labour and therefore I infer that you are strong and well. I can assure you that I have by no means forgotten my short and very pleasant interview with you.

Believe me, my dear Sir—

Yours sincerely,

(Signed) CH. DARWIN



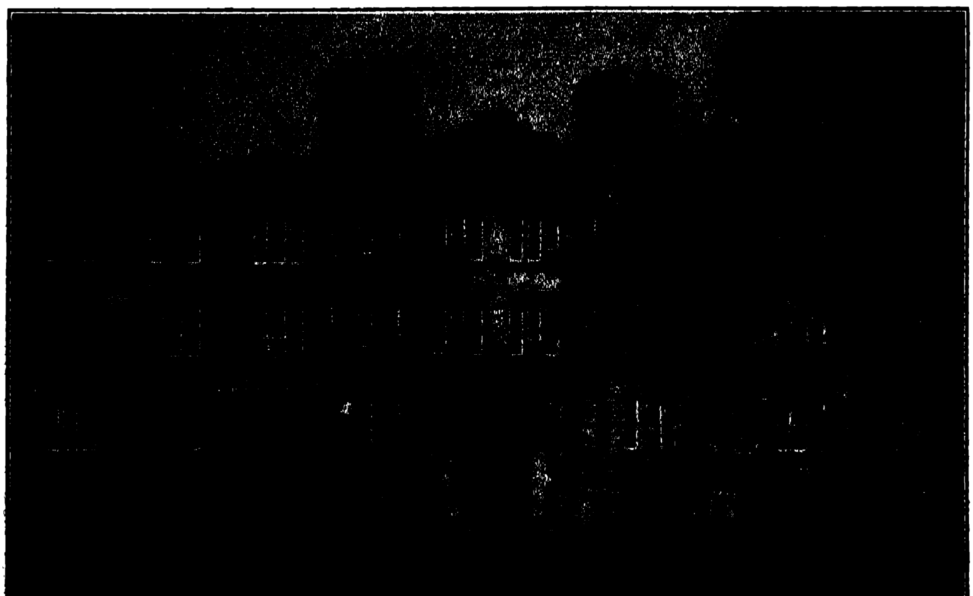
MAIN BUILDING OF VANDERBILT UNIVERSITY

THE PROGRESS OF SCIENCE

THE AMERICAN ASSOCIATION AT NASHVILLE

THE meeting of the American Association for the Advancement of Science and the affiliated national scientific societies at Nashville was successful beyond expectation. There were more than 1,200 addresses and papers on the program, which compares favorably with the meetings in the large cities of the eastern and central states. If each paper is of the average length of ten pages, when prepared for the press, then the proceedings, if printed in full, would fill twenty-four volumes. The issues of *Science* for January 27 and February 3 will be devoted to accounts of the meeting by the permanent secretary and the secretaries of the various organizations. These issues can be obtained free of charge from the office of the permanent secretary in the Smithsonian Institution, Washington, by members of the association who do not receive *Science*.

The opening general session was held on Monday evening in the auditorium of the beautiful Nashville War Memorial Building. The first address of welcome was made by Dr. James H. Kirkland, chancellor of Vanderbilt University, representing also The George Peabody College for Teachers, Ward Belmont School for Women and the Tennessee Academy of Science. The second address was by Judge Grafton Green, chief justice of the Supreme Bench of Tennessee, who began an address which maintained high standards of intellect and eloquence by relieving all embarrassment of visiting members through the explanation that as chief justice of the state he could assure them that no Tennessee law would interfere with any of their discussions, even if they were carried on in public schools not then in session. Any member of the association who might suppose that



CHEMICAL LABORATORIES OF VANDERBILT UNIVERSITY

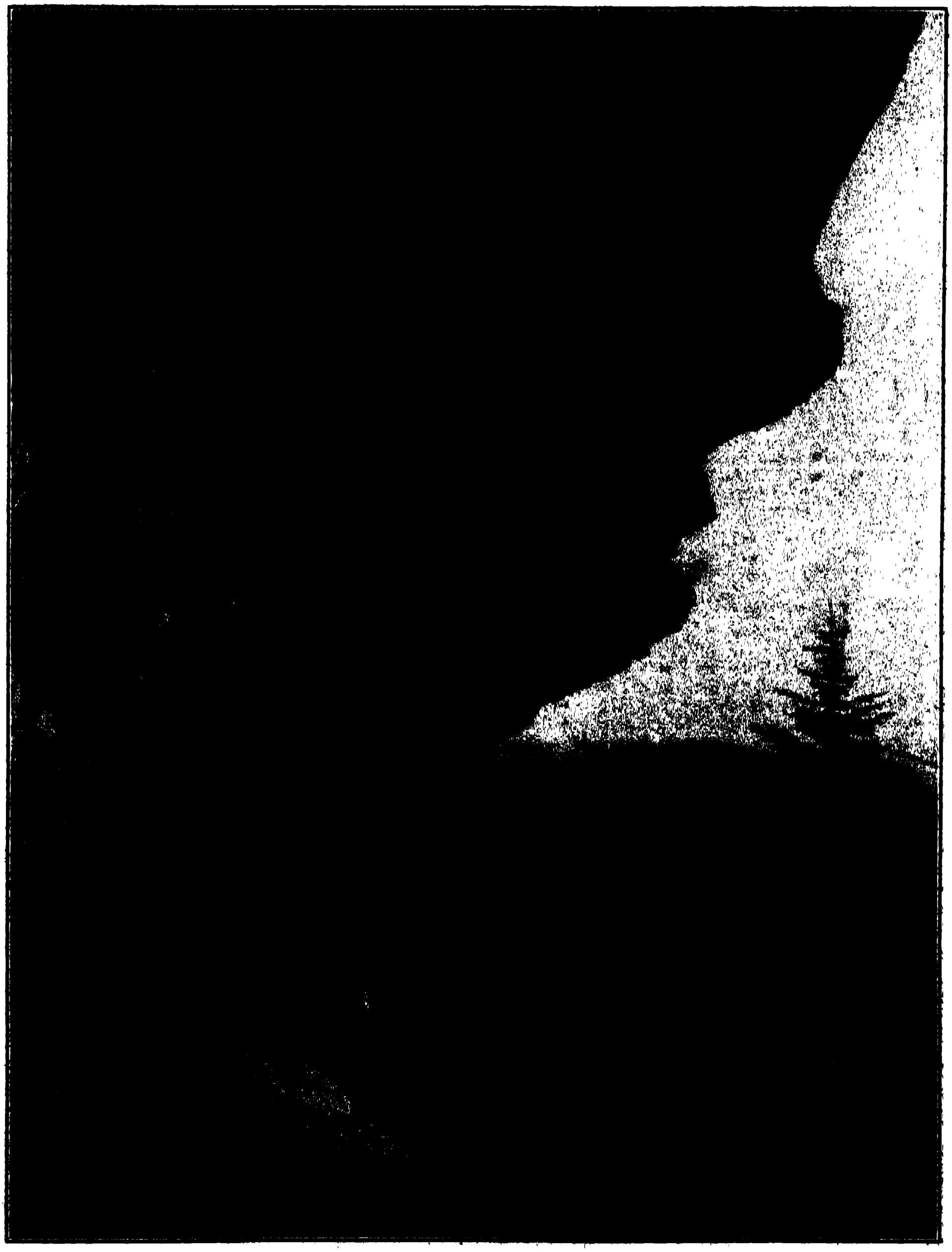
ADMINISTRATIVE BUILDING OF GEORGE PEABODY COLLEGE

missionary work on behalf of evolution was needed at Nashville must have had small knowledge of the high standing of the educational institutions of the city.

Dr. Arthur A. Noyes, of the California Institute of Technology, who then took the chair as president of the association, made an admirable address. The address of the retiring president, Dr. Liberty Hyde Bailey, which should have followed, was not given, owing to the serious illness from which Dr. Bailey is recovering, but too slowly to make it possible for him to be present at Nashville. In place of this address, Dr. Sylvanus G. Morley gave an illustrated lecture on the explorations of the Carnegie Institution in Yucatan, showing in a most interesting way the remarkable culture developed 2,000 years ago by the Maya in southern Mexico and northern Central America.

Brief references only can be made to other general sessions, which included the sixth annual Sigma Xi lecture, by Dr. Clarence C. Little, of the University of Michigan, who spoke on research in mammalian genetics, to which subject he has made notable contributions continued even with the multifarious engagements of a university president. The fifth Josiah Willard Gibbs lecture, under the auspices of the American Mathematical Society, was given by Dr. Ernest W. Brown, professor at Yale University, as was Gibbs. Dr. Robert C. Aitken, director of the Lick Observatory, gave an address on Edward Emerson Barnard, one of the greatest American astronomers, who was born in Nashville in 1857.

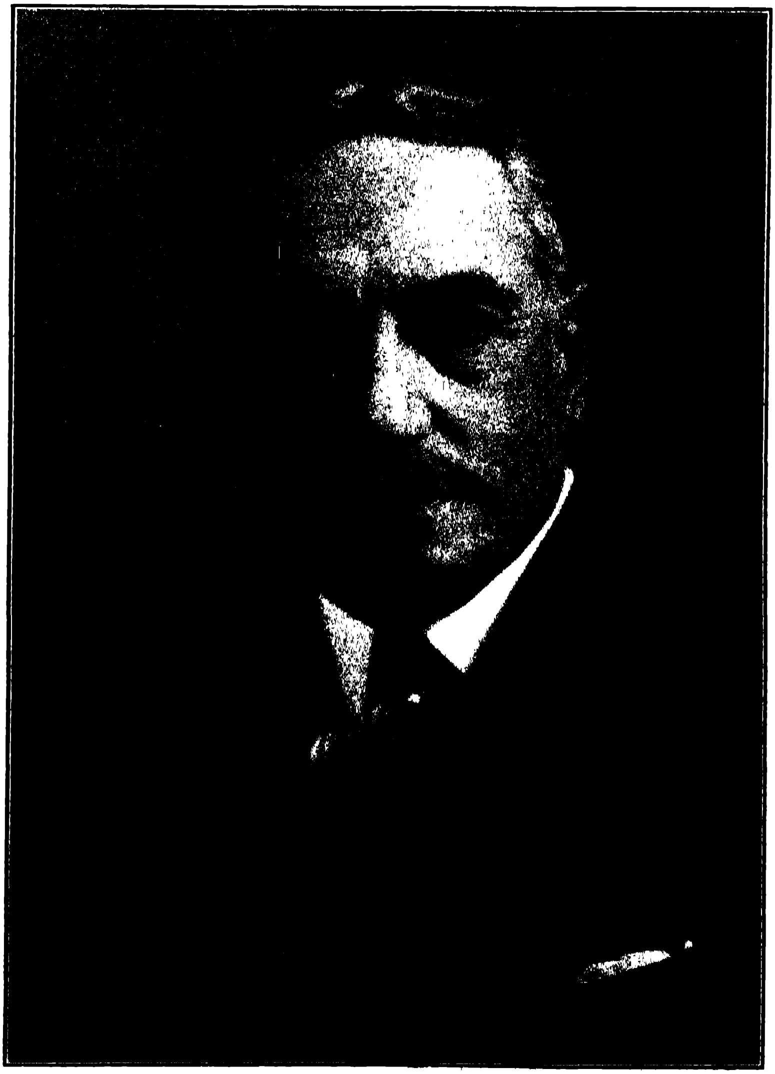
Dr. W. E. Ritter, emeritus professor of zoology in the University of California and director of the Scripps Institution of Oceanography, recently serving as president of Science Service, lectured on science and the newspapers. The distribution of scientific knowledge was also the subject of an all-day discussion arranged by Austin H. Clark, of the Smithsonian Institution, who has for several years been in charge of the press service of the association. Another symposium of general interest, arranged by Dr. Rodney H. True, secretary of the Association's Committee of One Hundred on Scientific Research,



ALUM CAVE BLUFF
ON THE SOUTH SIDE OF MOUNT LE CONTE IN THE GREAT SMOKY MOUNTAINS

PROFESSOR A. A. NOYES

RETIRING PRESIDENT OF THE AMERICAN ASSOCIATION. THE PHOTOGRAPH WAS TAKEN AT THE ENTRANCE OF THE GATES CHEMICAL LABORATORY, CALIFORNIA INSTITUTE OF TECHNOLOGY, OF WHICH PROFESSOR NOYES IS DIRECTOR.



DR. HENRY FAIRFIELD OSBORN

PRESIDENT OF THE AMERICAN ASSOCIATION. DR. OSBORN IS PRESIDENT OF THE AMERICAN MUSEUM OF NATURAL HISTORY AND RESEARCH PROFESSOR OF ZOOLOGY IN COLUMBIA UNIVERSITY.

was on the economic relations of science workers.

Among excursions were a visit to the "Hermitage," the home of Andrew Jackson, in the vicinity of the city and a long excursion following the meeting to the Great Smoky Mountains as guests of the Chamber of Commerce. A national park is planned there, where the flora and fauna are exceptionally rich and many peaks rise to more than 6,000 feet above sea-level.

AN INTERNATIONAL CONGRESS OF PSYCHOLOGY IN AMERICA

THE international scientific congresses that have developed in the course of the past fifty years have contributed much to the advancement of science by promoting the exchange of information and increasing friendly intercourse among scientific men. This is accomplished not only at the meetings, but remains afterwards as a permanent endowment yielding high dividends paid in mutual understanding and good-will.

The resumption of international congresses after the war was needlessly delayed by the action of the National Research Councils established largely as war measures and carrying over to the relations of scientific men emotional attitudes that it is their business to minimize. Scientific men of nations with whom we had been at peace for years were even excluded from the International Congress of Mathematicians held at Toronto in 1926. The congresses for psychology and physiology, held, respectively, in Oxford and in Edinburgh in 1923, were the first in which all nations were invited to take part on equal terms. Now these two congresses have arranged to meet in America in 1929.

International congresses for botany, soil sciences and philosophy were held here last year, and there will now be international congresses in all the sciences with a tendency to meet in the United States. Before the war there had been held here successful congresses in chemistry and in zoology, but in general there had been difficulties in the way of obtaining the attendance of European men of science, the psychological distance westward being much longer than eastward. Plans were made for a psychological congress in the United States in 1912, but it appeared to be doubtful whether there would be a considerable attendance from abroad unless we were prepared to pay the traveling expenses of foreign members, their general attitude at that time being that we could supply the money and they would supply the science.

At the Oxford Congress a preference was expressed for a congress in America in 1926, but it was finally held in Holland. The congress of next year follows an invitation of the American Psychological Association decided on at the Philadelphia meeting a year ago. A committee on organization was then named and the officers and other members of the national committee were elected by a nominating and a formal ballot of members and associates of the association. At the recent Columbus meeting the plans for the congress were adopted and a meeting was held of the national committee, eighteen of the twenty-one members being present.

It is expected that the congress of 1929 will be the largest gathering of psychologists in the history of their science, which does not long antedate the first congress held in Paris in 1889, the first chair of psychology in any university having been established at the University of Pennsylvania in 1888. The American Psychological Association was organized in 1892, with twenty-six members, some of whom would not now be classed as psychologists. There are at present some six hundred members and two hundred associates, all of whom are or have been engaged in professional psychological work.

America surpasses every other country, perhaps all countries combined, in the number of its psychologists, and it is here that educational psychology has received its chief development. We are relatively backward in several other departments, such as medical and industrial psychology, so the congress should be of special value to all who take part in it. Provision will so far as possible be made to assist in defraying the cost of travel for foreign members by lectureship and similar engagements.

The congress will be held at Yale University, New Haven, Connecticut, probably in the week of September 1, 1929. The officers are: *President,* J. McKeen Cattell, New York; *Vice-president,* James R. Angell, Yale University; *Secretary,* Edwin G. Boring, Harvard University; *Treasurer,* R. S. Woodworth, Columbia University; *Foreign Secretary,* Herbert S. Langfeld, Princeton University; *Executive Secretary,* Walter S. Hunter, Clark University; *Chairman of the Program Committee,* Raymond Dodge, Yale University.

In addition the national committee includes J. E. Anderson, University of Minnesota; Madison Bentley, University of Illinois; E. A. Bott, University of Toronto; H. A. Carr, University of Chicago; Knight Dunlap, Johns Hopkins University; S. W. Fernberger, University of Pennsylvania; William McDougall, Duke University; W. B. Pillsbury, University of Michigan; C. E. Seashore, University of Iowa; L. M. Terman, Stanford University; E. L. Thorndike, Teachers College, Columbia University; H. C. Warren, Princeton University; M. F. Washburn, Vassar College, and R. M. Yerkes, Yale University.

ADVANCES IN BIOPHYSICS

The annual American Association prize of one thousand dollars is awarded each year to the author of a notable contribution to the advancement of science presented at the meeting of the association and the organizations that meet with it. This is not a competitive prize, as would be understood from newspaper reports, but a recognition of some paper of outstanding importance and interest. This year the award went to Professor H. J. Muller, of the University of Texas, one of several distinguished students and workers with Professor T. H. Morgan in the new field opened up by him in the study of mutations in the fruit-fly, *Drosophila.*

Professor Muller's recent work is perhaps not more important than his previous researches, but it is certainly of striking interest and his paper at the International Congress of Genetics in Berlin last summer, where comparisons were possible, was regarded as the leading contribution. An account of his work was given in the issue of this magazine for July last.

Briefly, Professor Muller finds that by treating the flies with X-rays, the genes, or hypothetical hereditary particles, are affected, so that mutations occur much more frequently, 150 times as often as in nature. If mutations can be produced artificially and at will in plants and animals, the work of the animal and plant breeder will be greatly accelerated. We shall no longer need an empirical genius, such as Burbank, but shall obtain our results by quantitative laboratory methods.

X-rays have long been the tool of the physicist in studying the intimate structure of matter, but only recently has the biologist begun to realize the fact that this form of energy can also throw light upon many of his problems. Medicine has, of course, utilized X-rays for many years as a method of observing and photographing the inner portions of the human body; and this form of radiation

is used extensively—and with fair success—in the treatment of cancer. Ultra-violet light has recently become important in the prevention and treatment of rickets and generally as a substitute for the sunlight cut off by modern methods of living.

Professor Muller's paper was by no means the only one at Nashville concerned with the effects of radiations on organisms. Professor Winterton C. Curtis and Raymond A. Ritter, of the department of zoology at the University of Missouri, told of their researches on the effects of X-rays on the development of growing tissue. Professor Frank B. Hanson, of Washington University, St. Louis, who has been collaborating with Professor Muller, reported the effects of the rays on the rapidity with which flies reproduce. Professor Robert T. Hance, of the University of Pittsburgh, told of some of the first results of X-ray experiments on warm-blooded animals. The hair color of mice exposed to very light doses of the rays in his laboratory was radically changed. Dr. H. J. Bagg, of the Memorial Hospital, New York City, and Dr. Clarence R. Halter, working in collaboration, were among the first to obtain positive results with warm-blooded animals. Their mice developed certain marked bodily defects, such as possessing only one kidney instead of two, abnormal eyes, and legs in bad condition at birth. Such defects, like the mutations caused by Dr. Muller, occur among mice bred under ordinary conditions, but not so often as among X-rayed animals.

Plants as well as animals respond to X-ray treatment. Professor T. H. Goodspeed, of the University of California, has obtained results in the breeding of X-rayed tobacco plants which are comparable with those of Professor Muller on fruit-flies. The new varieties produced in this way have a stronger growth and produce more flowers than their cousins descended from un-rayed parents. Professor L. J. Stadler, of the University of Missouri, has conducted similar experiments with corn and barley.

Ultra-violet radiation, now widely used for the promotion of human health, has been shown to be able to promote plant growth as well, and to increase the production of valuable plant ingredients. Experiments in this field were reported before the Botanical Society of America by Miss Adelia McCrea, of Parke, Davis and Company, Detroit. Ultra-violet light has the power to kill as well as cure. Experiments were reported by Professor A. Brooker Klugh, of Queen's University, Kingston, Canada, showing that the short length ultra-violet radiations of the sun are deadly to the minute crustacea that furnish food for the fish of commerce.

PROFESSOR J. VON WAGNER-JAUREGG: NOBEL PRIZE WINNER, 1927

THE disease general paresis or dementia paralytica has been well recognized now for over a century. The description of it in Ibsen's *Ghosts* is but little overdrawn. Besides being one of the commonest forms of insanity, it has always been regarded as one of the most hopeless. The treatment by synthetic arsenic compounds which is so effective with other forms of syphilis usually serves only to make it worse.

In 1887, von Wagner-Jauregg, at that time a young assistant in the great psychiatric clinic in Vienna, undertook to look up the cases in which spontaneous recovery had occurred in this supposedly incurable disease. He found that some intercurrent febrile infection had ushered in the improvement in a large majority of such cases. It was but a step to think of inducing an artificial fever; but febrile states are not

PROFESSOR J. VON WAGNER-JAUREGG

easy to produce and control at will. He tried the effect of administration of small amounts of tuberculin, which brought about temporary improvement in some instances. This proved enough of a success to prompt him to use typhoid vaccine intravenously in a series of cases some years later. However, the benefit was never sufficiently striking or permanent to cause psychiatrists elsewhere to take up the treatment, and in general little notice was taken of it. The discovery of salvarsan in 1905 completely eclipsed further similar therapeutic experiments for several years.

Meanwhile, the young assistant found many other things to occupy his mind. He became privat-docent, and finally professor. His practice grew, and always with it his reputation as a sympathetic, careful, skilled physician. He conducted various clinical and anatomical *Arbeiten.* Of these, one stands out with particular sharpness to-day: the suggestion that iodine should be added to table-salt for the prevention of goiter, as is now being done on a large scale in this country and in Europe. von Wagner-Jauregg revived the idea—which, however, was not original with him—in 1892, and produced fresh evidences of its advisability. Although his recommendations were not put into practice, they undoubtedly paved the way for the recent work of Marine and others which has proved of such great importance.

The further development of the fever treatment of paresis was in a sense a result of the war. Malaria was unknown in Austria for many years, until brought back by soldiers returning from Italy and the Eastern front. Here for the first time were many fresh cases of a recurrent paroxysmal febrile disease whose course was well known and one for which an effective remedy was at hand. The experiment of transmitting a second serious disease to a patient with paresis was easily justifiable in view of the utterly hopeless prognosis of the latter condition. Perhaps, however, it was also easier for the professor—now also *Hofrat*—than for the assistant of thirty years before. So in 1917, von Wagner-Jauregg inoculated nine paretics from a soldier with untreated tertian malaria, allowed them to have a series of several chills, and then administered quinine. All were improved; and on investigation, four years later, three of them were found to be alive and able to work—an unprecedented success. It was found that the inoculated malaria ran a benign course, and could be safely and surely cured at will by a single dose of quinine.

The report of the first cases was met with general skepticism, which has been only gradually overcome. France and the United States have been perhaps the most conservative, but even here the treatment is being used on a large scale, and the reported results are favorable. Naturally, early cases respond much better than advanced ones. Various modifications of the treatment have been suggested—for example, the intensification of the fever by means of hot baths, and the use of the spirillum of relapsing fever instead of the malarial parasite—but von Wagner-Jauregg's original method is still the standard. The treatment has also been extended to other conditions, but it is still too early to estimate its value in them. Encephalitis and multiple sclerosis appear to be little affected by it, but favorable reports of its use in primary syphilis and locomotor ataxia are available.

Professor von Wagner-Jauregg's seventieth birthday was celebrated in April of this year. It is fitting enough that the whole scientific world should join his patients and his students in their congratulations.

T. J. P.

THE SCIENTIFIC MONTHLY

MARCH, 1928

BUILDING A MUSEUM TO HUMAN SPECIFICATIONS

By Dr. F. C. BROWN

MUSEUMS OF THE PEACEFUL ARTS

BACK as far as 1916 there was recognized such a thing as museum fatigue. B. I. Gilman[1] discussed this subject at some length. He showed a number of pictures in which the visitor was unnecessarily fatigued because things to be seen were displayed in a wrong manner. The pictures showed the visitor in all positions, from standing stretched outright on top of a chair to resting with knees on the floor.

In the same year *The Literary Digest* had an article on treating museum fag.[2] In quoting the New York *Sun*, "The Truth is, very few of us know how to use a museum," and it thinks that there should be schools in which we might learn. "A well known art critic once said that fifteen minutes was as long as any normally constituted intelligence could react on the stimulus furnished by a picture." "Perhaps it would be well to begin the reformatory work with a certain degree of violence. Might not each visitor unable to produce credentials certifying to his capacity to visit the institution, prudently be chained in front of one of the exhibits? Thus he would be compelled to give attention to the treasures brought together for his edification, and restrained from the madness of movement that seizes some people when they pass the portal. In this way, museum fag would be impossible and more of us could enjoy the good things that now so few of us know how to use."

In *The Century*, of January, 1926, F. H. Cooke[3] discusses the subject of "Culture and Fatigue, being some reflections on museums." He says, "Whenever we exhibit things that make for wisdom or beauty, there, I take it, is a museum. It should really be a temple of the muses, but to most of us it is merely an extensive store house where we get tired." He would provide plenty of chairs. "What we most need, however, is occasional ruthless directors who have the strength of mind and skill to weed out all inferior or extraneous matter and box it, burn it or give it away." "It is in fulfilling this function, of giving inspiration for future endeavors, that our museums are apt to fail." "We suffer from the mania of collecting things."

It is obvious, therefore, that museum fatigue is a real and not a fictitious thing. The *Sun* has rather expressed the viewpoint that perhaps folks should be made over, but I am inclined distinctly to the view of Cooke, that the museum should be built to human specification. One museum which can be built to human specification is an indus-

[1] THE SCIENTIFIC MONTHLY, Volume II, pages 62–74, January, 1916.

[2] *The Literary Digest*, 52–1151, 1916.

[3] *The Century*, January, 1926, 111–291.

VISITOR INSPECTING A CROSS-SECTION OF THE ACTION OF A PLAYER PIANO REGISTERING THE INTENSITY OF THE HAMMER BLOW BY DEPRESSION OF THE KEY AT THE RIGHT AND AT THE SAME TIME PRODUCING THE SAME BLOW BY MEANS OF THE PNEUMATIC CONTROL AT THE LEFT

INSPECTING THE INSIDE OF A RIFLE BARREL THROUGH THE MINIATURE PERISCOPE. THE VISITOR OPERATES THIS EXHIBIT BY PRESSING THE PUSH BUTTON WITH HIS LEFT HAND AND EXAMINES THE DIFFERENT SECTIONS OF THE INSIDE OF THE BARREL BY TURNING THE CRANK WITH HIS RIGHT

trial museum. Such an institution can collect and conserve the record of man's industrial accomplishment and at the same time present these records in a manner to stimulate and educate either the layman or the expert.

If a museum is to be built for the lay public, the problem is, to a considerable extent, one for the practical psychologist to solve. Granting that the ultimate purpose of the museum is essentially

LISTENING TO THE MUSIC PRODUCED BY A MODEL OF AN EARLY PHONOGRAPH WHICH IS OPERATED BY THE HAND

educational, we have the same problems that confront an educator who is conducting his work without the moral suasion of grades, prizes, diplomas, and the like.

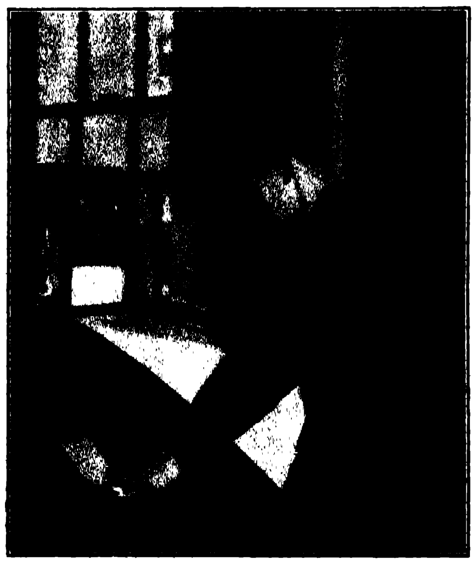
The first problem, then, of the museum is to gain and maintain its audiences. This means that the visitor should be interested to such an extent that he will desire to return and that he will tell his friends of the profit he has received with a minimum expenditure of energy. After his visit he should not be conscious of severe fatigue to any greater degree

MEASURING IN 1/100,000THS OF AN INCH, BY MEANS OF BANDS OF LIGHT WAVES, THE DEFLECTION OF A STEEL RAIL CAUSED BY THE SLIGHT PRESSURE OF A FINGER ON THE TOP OF THE RAIL

THE COMFORTABLE POSITION OF THE VISITOR WHEN HE VIEWS THE ALPHA RAYS GIVEN OFF BY THE RADIO-ACTIVE ELEMENT POLONIUM

than after a good game of golf, and he should carry away an inspiration and wonder that will strongly impel him to seek further information through means which, in many cases, may be suggested by his visit to the museum.

There are first the purely physical considerations. The temperature and humidity should be as agreeable as possible, and the air and objects should have a minimum of dust and dirt. Wraps



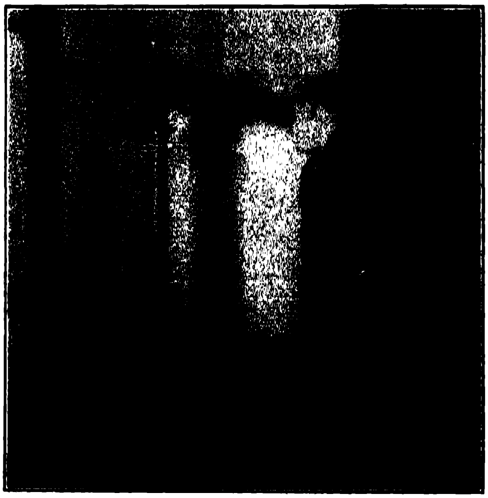
VISITOR INSPECTING THE DAYLIGHT RECORDING APPARATUS WITH THE CHART GIVING THE INTENSITIES OF THE DAYLIGHT FOR EVERY MINUTE OF THE DAY AND COMPARING THIS ILLUMINATION WITH THAT FROM A CONTROLLED SEARCHLIGHT AT THE RIGHT

and packages should be deposited when entering. Much of the walk way surface should be easy on the feet and during the entourage of the museum the visitor should have exercised as many different muscles as he would in his "daily dozen." Chairs and stools should be thoughtfully interspersed throughout the exhibits and provision should be made for accessible dining and lunching as would enable the hungry visitor to

lengthen his visit and encourage him to make frequent trips to the museum.

The Museums of the Peaceful Arts is conducting a demonstration museum, essentially for invited visitors, in which it is studying the problem preparatory to the establishment of a great industrial museum in the City of New York. With reference to museum fatigue, it has been found that no visitor, even after many hours, has expressed himself as being weary. We may, therefore, call attention to some of the exhibits which seem to the author to be the basis of absence of fatigue.

One of the first exhibits which the visitor sees is from the Research Laboratories of the American Piano Company. He presses one button and hears sketches of music on a player piano. Pressure gages show him the variation of air pressure that produces the varying intensity in the music. When his interest is satisfied on this point he presses the button again, and the music stops. When all the sketches have been played, the music rewinds itself. Before him is a cross section showing how the action



Visitor looking through an original Fraunhofer telescope

in the piano is carried out. He hits the piano key and can see the purpose of the various parts. There is a pointer which registers the intensity with which he hits the piano key, and if he is a musician, he can check his own consistency. Further, by pressing the button, before his eyes he can see how the piano action is carried out by controlled air pressure, and he can set the mechanism on a dial and have the air pressure produce any desired intensity, which, to his surprise, repeats more accurately than he is able to do by striking the piano key.

By pressing the push button at the left the visitor sees the light bands of interference which move across a scale when the knob at the right is turned, thus showing how accurate measurements are made

Near by is a model of the first Victrola, upon which the visitor can himself produce music so long as he turns the crank, and he sees there how the governor prevents an excess speed of the turntable when the crank is turned too fast. Following this, he can see and operate the later models of the Victrola.

A few steps away is encased in glass a gun barrel camera, designed and built by the Bureau of Standards. By stooping over and pressing a button with the left hand, the visitor sees the rifling and the erosion of an army rifle barrel. With his right hand he turns a crank which connects inside the case and moves

the rifle barrel to different positions, so that he can see any part of the inside just as clearly as if he were to examine the barrel when it is sawed open.

The visitor then turns his eyes to a section of an eighty-pound steel rail, and, without bothering to read labels, he presses a button before him and a mercury vapor light gives its ghastly hue. Beyond this steel rail he observes Newton's rings produced between two optical glass surfaces, and then, noting the pictures and the label before him, he finds that if he will look into an eye-piece on the steel rail, he will there see the light interference fringes, and quite to his consternation, he presses with considerable force on the steel rail and finds that he can bend the rail by seven or eight wave-lengths of light. And like the man who stood in front of the giraffe, he is inclined to say, "There ain't no such animal." But what he usually says is either, "I didn't know that I could bend a steel rail" or "I didn't know that you could measure such small changes by any method." Even the technical student who is familiar with interference rings can study their application to research and industry.

Thus it is to be noted that the visitor, while on his feet, is in various attitudes

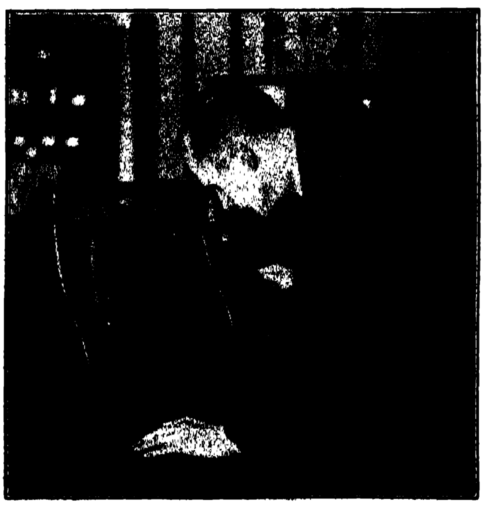
THE VISITOR IS FASCINATED AT THE DIFFERENT EXPRESSIONS AN OBJECT TAKES ON UNDER DIFFERENT LIGHTING CONDITIONS PRODUCED BY THE THREE-WAY SWITCH AT THE RIGHT

THE VISITOR HERE IS ABLE TO STUDY THE MOVEMENTS OF ROTATING APPARATUS BY LOOKING THROUGH THE ROTATING SLOTS OF THE STROBOSCOPE AND MAKING THE PROPER ADJUSTMENTS ON THE SLIDING BAR AT THE FRONT

and positions, almost comparable to those in a game of golf. But for fear that he is tired of standing, he notes a telephone booth which is labeled "Radium Exhibit." By reading the label on this booth, he learns that if he will seat himself inside, he may see alpha rays from radium striking upon a zinc sulphide screen, and that further he may press two small keys, not unlike piano keys, and bring either a sheet of writing paper or an extremely thin sheet of mica in the path of these rays. He does this and finds that the sheet of writing paper completely stops the alpha rays, and further, that the mica is so thin that a number of the alpha rays pass right through it.

The visitor then turns to the Daylight Recorder, a joint exhibit of Leeds and Northrup Company and the Case Research Laboratories. He sees on the cross-ruled paper the continuous record of the sunshine on the top of the 17-story building, and on the same sheet, the record of the light intensity in the room. He sees that this double point recorder alternately makes the record of the light variation on the roof and in the room.

CLOSE EXAMINATION OF SMALL ARTICLES FOR THE PURPOSE OF THOROUGH STUDY IS AFFORDED THE INTERESTED VISITOR



BY MEANS OF THIS AUTOMATIC SCREW MACHINE THE VISITOR IS ABLE TO STUDY OUT THE COMPLETE PROCESSES OF MANUFACTURE CARRIED OUT IN THE LARGER MACHINE.

He presses the button and increases the light intensity on the Case photo-electric cell in the room, and with his right hand changes the resistance in a rheostat, so as to bring this light intensity to any desired value.

He then may go over to an old Fraunhofer telescope which Fraunhofer made just a few years after he had discovered the lines in the solar spectrum (about 1818). The visitor not only observes the remarkable machine work on the instrument, but he looks through an opening in the window to a neighboring sky-

EXAMINING THE MOVEMENTS OF THE ORIGINAL ELI WHITNEY MILLING MACHINE

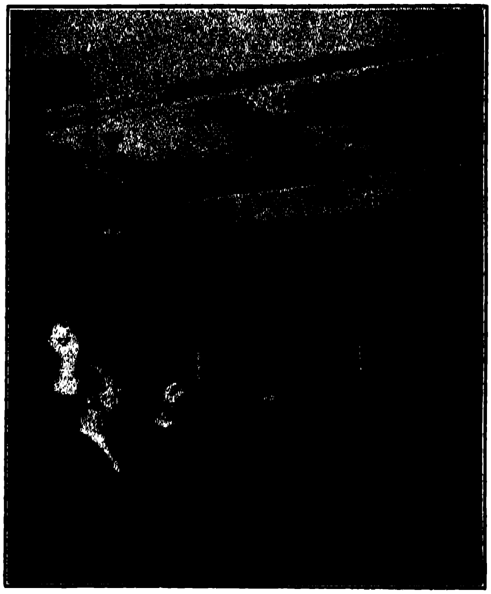
scraper. As a layman, he may be surprised to find the object which he views upside down.

The visitor now may go to an exhibit showing the relationship between a dial gage with divisions one ten-thousandth of an inch apart to light interference fringes. Using his left hand and looking into the interferometer, he sees the fringes. With his left hand he moves the dial gage and counts the number of fringes that pass by. Thus he obtains for himself an accurate knowledge of the wave-length of light.

Not far away is a simple stroboscope, where the visitor presses a button and can make the blades of an electric fan apparently go forward, backward or stand still, at will. Thus he gains information to explain why the wheels of an automobile, as seen at the "movie," sometimes seem to be revolving backwards, while the machine is obviously going forward.

It is possible to make many studies of illumination by what some have called the "cafeteria" method. The visitor may wiggle a button in different positions and find that the plaster cast looks entirely different, depending upon the direction from which the illumination comes. This is merely one of many similar exhibits from the Engineering Department of the National Lamp Works.

At one end of the museum is an old key suspended by a string leading up to a kite in a make-believe clouded sky. There is a picture of Benjamin Franklin and a framed statement telling of his experiment "drawing lightning from the clouds." The visitor is led to wonder and to read; bringing his hand near the key, he receives a spark of lightning. His imagination comes into play automatically.



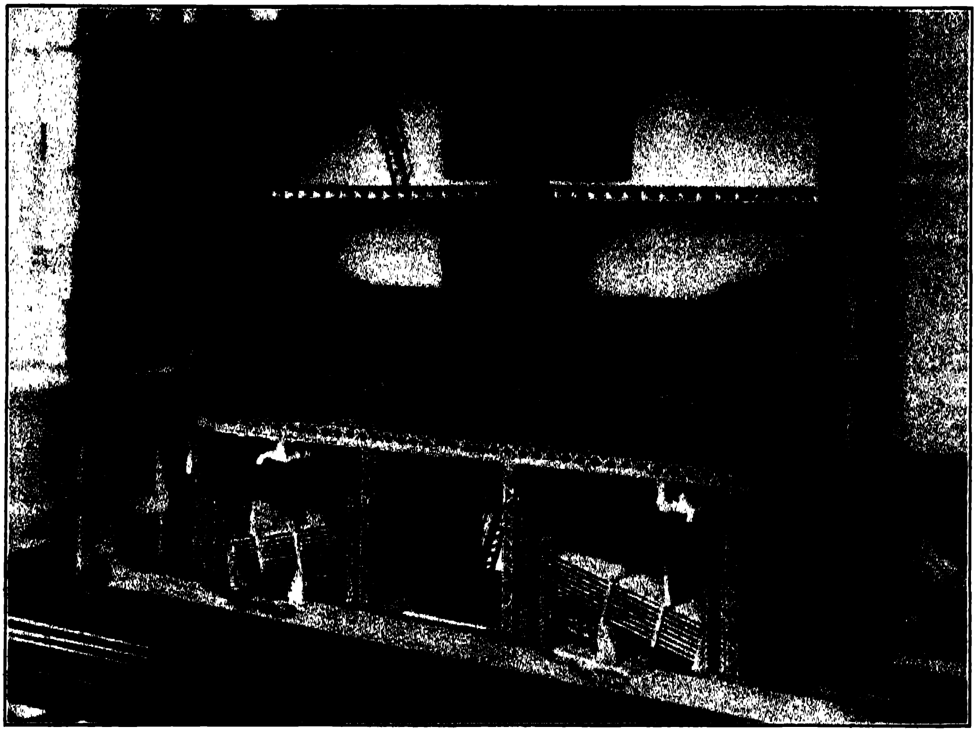
STUDENT TAKING LIGHTNING FROM THE CLOUDS

THE VISITOR IS ENABLED TO TYPEWRITE SHORT MESSAGES TO FRIENDS IN OTHER CITIES ON ONE OF THE ORIGINAL HALL TYPEWRITERS

A somewhat different character of exhibit is Eli Whitney's old milling machine, which is believed to be the oldest in the world. In spite of its age, the visitor can put his hands at various places and gain information as to how this machine once worked. Also, he can turn the crank on the model of the first automatic screw machine which the Brown & Sharpe Company produced. Unless he is familiar with such machines, this is likely to bring his imagination into play as well as his right arm.

Quite another type of exhibit is the model of the world's first electric power distribution station, namely the Pearl Street Station. Here the visitor merely looks, and since he has been participating in so many exhibits, interest alone holds his attention.

There is an old Hall typewriter which the visitor may operate in order to see in what ways it functions differently from the most modern typewriter.



MODEL SHOWING IN COMPLETE DETAIL THE EQUIPMENT USED IN THE FIRST ELECTRIC POWER PLANT IN NEW YORK CITY

Still a different type of exhibit that is common in the museum is that which the visitor can pick up and turn over without doing damage. For example, he may pick up and closely inspect a complicated work-holding device, such as is shown in the picture.

A point that is common in this exhibit as well as in the great preponderance of exhibits in the Museum, is visitor participation. It is somewhat like the old lady who reported that it was a very fine prayer meeting because she took part in it herself. The visitor in such a museum as we are describing should be fatigued to a minimum extent, because of the variety of muscles that are brought into play and because throughout he is conscious of his own participation.

The old saying that you can catch more flies with sugar than with vinegar is applicable to any museum that measures its success in terms of number of visitors multiplied by the degree of interest aroused. The fly is neither attracted nor held to sugar by its color or its shape. The museum visitors are not flies; nevertheless, it takes more than proper beauty and magnitude to attract and capture large numbers of our population.

The exhibits must have fundamental interest. It may be a debatable question whether any museum of science and industry can effectively arouse as great an interest as a prize fight or a football game. Personally, I believe it is possible.

Once an appeal has been established, the visitor's interest will follow a certain amount of tedious, difficult and uninviting exhibits, charts and reading matter, without great fatigue. Unrelieved wis-

dom may bore one, but a wise man may be worthwhile at a dinner party, providing there are also charming personalities and appetizing food. A museum should maintain itself on a lofty plain, but we should compromise with human nature to interest visitors in what we know is worth while. An industrial museum can succeed only in proportion to the visitors it interests. Thousands annually travel more than hundreds of miles to visit the Deutsches Museum at Munich; it is nevertheless of great advantage to have the museum accessible. Millions should be able to reach it within a half hour's journey. The visitor, having arrived at the museum, should find the building without difficulty, and its appearance should make his heart beat faster, much in the same manner as when, in his boyhood days, he arrived near the old swimming hole.

I do not in any way minimize the importance of the great museums that have been built, and it is not our idea that an industrial museum should be a gymnasium or a variety show. But, with the help of the psychologist and the teacher, it is hoped that an institution can be built which will both attract and educate. Well chosen exhibits will make the path of knowledge easier and more attractive both to the research worker and the layman. Special exhibits may be available to the research worker alone.

In speaking of industrial museums, Professor D. C. Miller said in part: "It seems to me that a museum like the Deutsches Museum will do more to develop technical and elementary scientific education than can ever be accomplished in the technical schools and universities. It would do more to educate the common people, ordinary inventors, etc."

The industrial museum should be the embodiment not only of the material forces that have characterized the last century, but should show the upward climb from first beginnings to the present day. It should treat the visitor on the basis of his integrated ancestral experience of hundreds of centuries.

INTERNAL SECRETIONS IN EVOLUTION AND REPRODUCTION[1]

By Dr. OSCAR RIDDLE

CARNEGIE INSTITUTION OF WASHINGTON

THOSE who attend lectures on scientific subjects are, in these days, especially captivated by the revelations of the physicist and the astronomer. Such interest is of course a well-deserved tribute to those who have taken the atom apart, permitting us a charmed look at its pieces; and a tribute to those others who have presented us with a quite new and gripping conception of the extent and structure of the universe. You have doubtless come under the spell of these bold, clear, new truths concerning the infinitely small and the infinitely large; and I must half suspect that many of you are even now thinking of atoms or of stars. To get your consideration of the subject of this hour it is therefore probably necessary, first of all, for me to locate properly in time, space and mass the type of objects which we here purpose to discuss.

From stars or atoms we must make the long journey to the *living* world; and, in the matter of size or mass, the distance—to an animal of the weight of man—is about equally long if we start from the atom or from the star. An eminent British astronomer has calculated that the number of atoms in the body of a man is represented by 10 to the 27th power, while the number of men required to equal the weight of a star is found by taking 10 to the 28th power. How natural, then, is man's pride concerning his position in the universe!

In getting our subject located in duration, or in time, we apparently have to concede that our living world is much *younger* than either atoms or stars. But we can be fairly certain that two of the processes with which we are now concerned—organic evolution and reproduction—are as old as the oldest organisms; also, that sexuality is somewhat less old, possibly spanning not more than half the years between the present and the first living matter on the earth; and finally, that the internal secretions are among the most recent acquisitions of even the higher animals. So recent are some of these secretions—which also pass under the names of hormones and endocrines—that our closest cousins, the mammals, may be said to have invented one or two; and those superior animals which are provided with backbones have probably originated much more than a majority of all the true hormones now known.

If these words carry some indication of the size and time relations of our general subject, it still remains to delimit its relations in space; for, here again we apparently need to concede important limitations. Life is known to exist only at points very near the *surface* of our own planet. If it exists in other worlds it seems likely to be limited to similar surfaces there, unless indeed in those other worlds living matter has developed with quite different properties and relationships than any types of life known to exist on our planet.

Compared with that of the physicist and the astronomer how very minute and limited is this stage on which our material is found! The atom the physicist can get from all depths and heights of our planet, and from any part of the chance meteor that comes to earth from

[1] A lecture delivered at the Carnegie Institution of Washington on the evening of November 15, 1927.

anywhere in space; and, atoms of the same kind behave alike, irrespective of the source of the electrons that enter into them. Another star, or even a new galaxy or universe, the astronomer readily gets by an improvement in his search in most any direction. Again, a beam of light that may have started on its way to the earth millions of years ago supplies much of the standard material now studied by both the physicist and the astronomer. The effort of each of those workers has proved most helpful in solving the problems of the other, and those among them who study the hot stars have even the crowning good fortune of finding matter in its simplest state—gases made up of atoms and broken atoms, atoms stripped of electrons.

With the help of these contrasts let us try to grasp the difficulties of him who would study the performances of matter in the living world, a world built of units always enormously large and complex as compared with the atom. Here is the great chaos of giant molecules—of orderly aggregations continuously displaying the new and difficult properties of living matter—in which the biologist and chemist grope as best they can. Living matter always exists and carries on at low temperatures, and it is precisely at low temperatures that matter exhibits its more troublesome properties.

Perhaps then these few remarks may help you to refocus your lenses, and to warn you that in leaving star and atom for a living thing you have left utterly all there is of simplicity behind. During this hour, at least, we ask you to share the view that it is not an atom, not a stone, not an earth, not a star, not a universe, but a higher animal that embraces the sum of all complexities. If we succeed here in saying things that are simple enough, this must rest on the circumstance that we persistently speak of fragments—not of the whole—of an organism.

In the investigation of any process that occurs in living things we begin by following up the clues that have been provided by previous study. Despite the complexity of our living world the pioneering work of others has already provided some clues—and usually a few tools and methods—for the further examination of most conceivable subjects. Such clues were at hand for a study of a part of our present subject, namely, the problem of sexuality, or sexual reproduction. By chance, these suggestive leads had been found in the bird world—in doves and pigeons—and it thus happens that my studies and questions have been addressed chiefly to the tissues of these particular animals. It seems best here to discuss the various parts of our present subject in essentially the same order in which they were investigated. The original problem with us was to learn the chemical and biological nature of sex-difference. We shall see that problems concerning reproduction and the internal secretions arose at once, and that some aspects of the most fascinating of all problems, namely, organic evolution, have already crept into the unfinished study.

When either the trained biologist or the layman accomplishes a detached view of the human species as an animal species, his first reaction is perhaps that of self-congratulation at its complexity, and at its finish of structure, power and adjustment. His second thought will surely be caught and fixed upon the fact that the individuals of his species are divided, both in form and in function, into two distinct groups. In other words, he becomes conscious of an ever-present and far-reaching divergence of the sexes. When his attention is directed to any other of the thousands of species —any except the lowliest of living things —this second impression dealing with sex-difference will remain; and further reflection upon this fact will bring conviction that sex and sexual reproduction have long had very firm footing in the evolutional marches which led to the origin and survival of the animal world as it now exists.

From these and from other considerations the problem of the nature of the forces which give origin and direction to this nearly universal formation of the two sexes within each species is somewhat akin to the problem of the origin of species. Apart from occupying a nearly central place in biological theory, sexuality stands a problem of great interest and importance to most branches of knowledge and to quite all of mankind.

The further development of our subject requires the use of a number of illustrations. Fig. 1 will help to make clear the nature of the two clues which supplied a beginning for our studies. Whitman had observed that when doves or pigeons are induced throughout the year to lay large numbers of eggs, instead of their usual numbers, the normal proportion of the sexes does not remain constant. Equal numbers or an excess of males are produced from the eggs laid in the earlier part of the season—in winter and spring; but an excess of females arise from the eggs laid in summer or during the later part of the season. In our illustration a pairing of the eggs is indicated by a spacing of the circles which are used to represent the egg-yolks—or, as we can better call them, the ova. The seasonal change of size of the circles is also utilized to indicate the

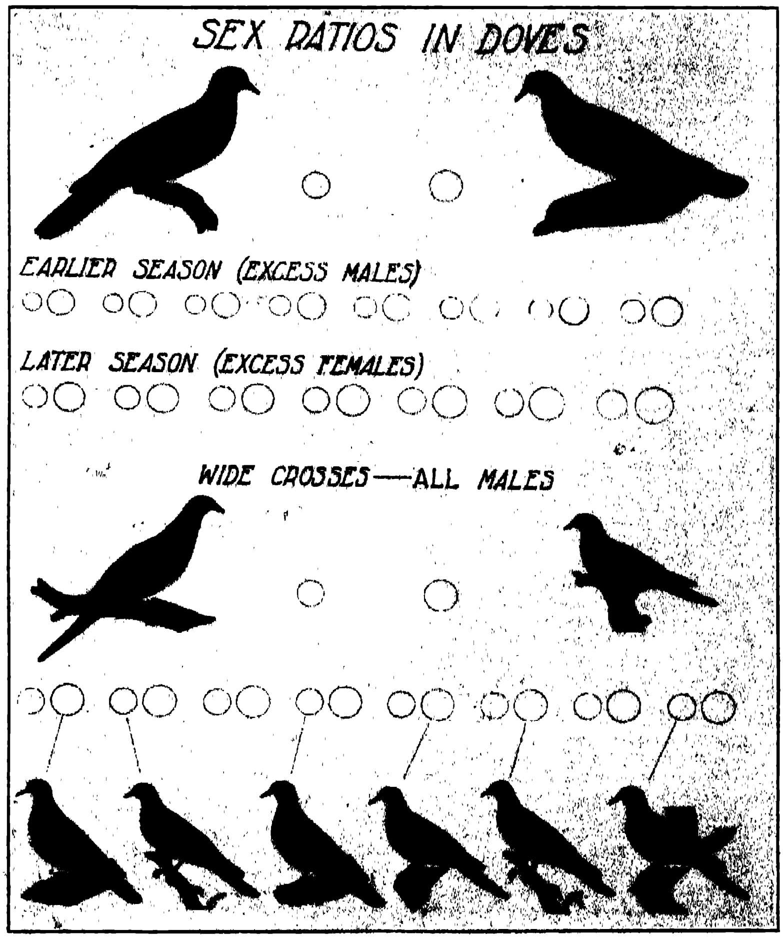


Fig. 1

first facts which we learned concerning the relation of yolk-size to the sex of the offspring. Those ova which are produced later in the season, and from which an excess of females develop, are in general larger than the eggs of late winter or spring which produce an excess of males. Our diagram considerably magnifies the differences actually found, but we are here content to have you observe that the ova increase in size from late winter to early autumn. Weights obtained on more than 20,000 ova have shown that this is the true relationship of season to yolk-size. Of course, size alone, without a knowledge of the chemical composition, is of rather uncertain meaning; but the clue provided by the seasonal change in sex ratio gave us an opportunity to take ova from all seasons of the year for chemical analysis. At the beginning we supposed that a chemical examination of these ova was all that we should do in connection with this subject.

The second clue provided by earlier work can be understood by reference to the lower part of this same diagram (Fig. 1). It had been observed that pigeons belonging to very different species, indeed to different zoological families, are partially fertile; that is, a part of the total number of eggs produced in the widest crosses are fertilized and develop. Here, however, one met the remarkable fact that all the offspring from these widest crosses are males; no females appear among the offspring of two parents which belong to two different zoological families.

Now the special interest attaching to this result lay in the circumstance that birds were known to produce two kinds of eggs, each kind being provided with the chromosomes or hereditary factors normally necessary to give rise to a male in one case, and to a female in the other. In mammals, including man, two kinds of sperm not two kinds of eggs are formed. Since two kinds of eggs are produced by birds, and yet males only result from wide crosses in pigeons, it seemed possible with the help of such crosses to test whether only male-producing eggs are fertilized and develop. Or whether, indeed, the then seemingly impossible thing happened, namely, that some eggs with chromosomes for femaleness are fertilized, but under these unusual conditions are forced to develop into individuals of the opposite or male sex.

Because of the circumstance that in most matings of such dissimilar birds only a few of the eggs laid are fertilized at all, it could be assumed that only male-producing eggs are fertilized. But even the then available facts did not well fit this view. On the diagram we indicate the result of our investigation of this topic. The males forming the row at the bottom are united by connecting lines to both types of ova; the large and the small, the male-producing and the female-producing. Unfortunately, time limits, and the main purpose of this address, will not here permit any real examination of the evidence for this conclusion.

From our point of view, both of these clues indicated that sexuality could here be investigated by chemical means; for, in these animals, it was the ova, not the microscopic sperm, that were sexually different; and a single ovum of a dove or pigeon is large enough to permit an adequate chemical examination. Particularly, the chemical differences which might appear between the eggs produced in early and late season should indicate the nature of the factors, other than genetic or hereditary factors, which underlie the development of the two sexes in these two particular conditions where the normal chromosomal control of sex development clearly fails, or is forced to new and unusual behavior.

It so happened that I was compelled to conduct not only chemical studies on these ova, but to carry on breeding experiments as well. Our procedure involved taking a portion of the eggs

produced by a bird at each of the several seasons for chemical examination; another portion for burning in a machine called a calorimeter; and to have the remaining eggs reared by a reserve battalion of foster-parents—some hundreds of doves kept solely for this purpose—so as to learn the sex which would result from these remaining eggs. The curves or polygons shown in Fig. 2 tell us, for

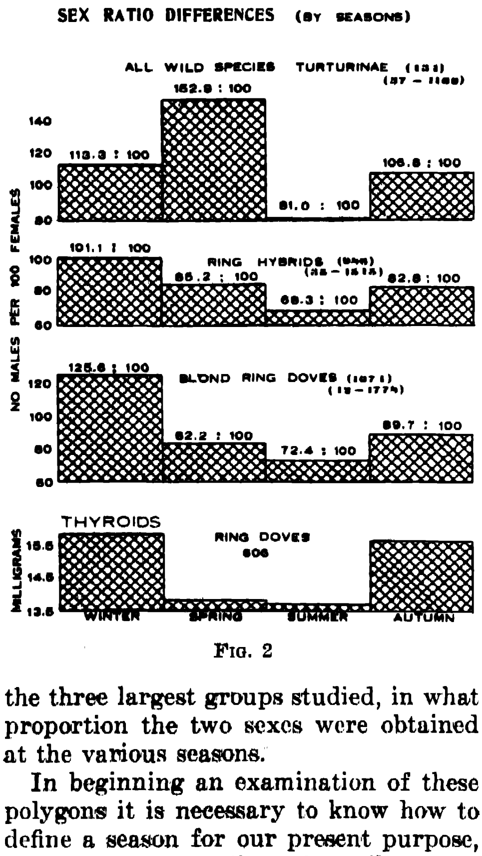


FIG. 2

the three largest groups studied, in what proportion the two sexes were obtained at the various seasons.

In beginning an examination of these polygons it is necessary to know how to define a season for our present purpose, and a momentary digression will permit us to explain how this has been done. Possibly the astronomer's calendar is not that of the pigeon; perhaps the dove has not sensed the equinox and the inclination of the earth's axis. After our results had indicated that the sex of the offspring is related to the rate of metabolism—*i.e.,* to the rate of burning and energy-release within the ova—it was plain that the right calendar to use in classifying all our data would be the "metabolic calendar" of the pigeon itself. In order to construct such a calendar for our animals we turned to their thyroid glands; for, in all warm blooded animals, these glands prepare and release an internal secretion which in large measure determines the rate at which they burn food and release heat. It was found that the thyroids of these animals enlarge during October, November and December, and perhaps attain even still larger size during January, February and March. This six-months' period, divided into halves, thus gives us the pigeon's autumn and winter. During the remaining six months the thyroids were found to be consistently smaller, and their structure indicated that they were also less active. These months, likewise divided into halves, give us the pigeon's spring and summer, which extends from the end of March to the end of September. Thus, after all, you see that the dove and his thyroid have been found to record with fair accuracy the position of the earth in its orbit round the sun.

In viewing Fig. 2 and the next following illustrations you are asked to note that seasonal differences, not the full values, are expressed on these polygons. The thyroids were largest in winter, smallest in summer. The sex of the offspring hatched within periods thus defined are shown here. The largest proportion of males is found in the winter or early spring when, for every hundred females, we obtained such numbers as 125 males, 101, 113 and 153 males. On the other hand, in every case the summer brought the greatest excess of females. For each hundred females there were in the various series only 72, 68 or 81 males. During the autumn period the parent birds could no longer be forced to rapid ovulations at a time when their thyroids were enlarging, so that during this period the sex ratio again approaches 100 males to 100 females.

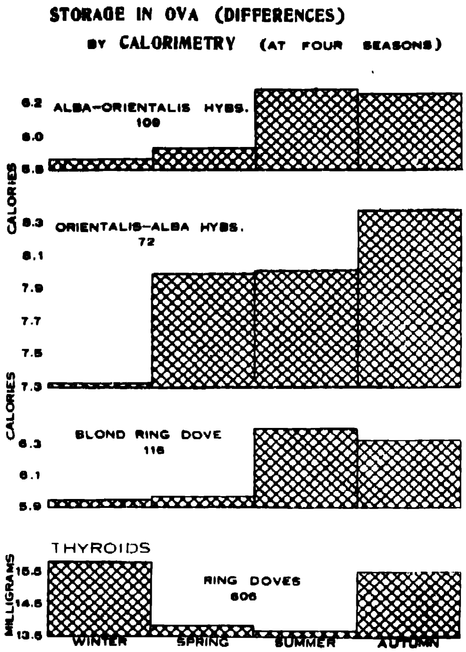


FIG. 3

In Fig. 3 are shown measurements of the amount of energy that was stored in ova produced during the four seasons. Individual yolks were burned in a bomb-calorimeter—an apparatus that accurately measures energy released in the form of heat. The seasonal average of some hundreds of such single determinations are plotted on these polygons. It is plain that least material is stored in the winter and spring—the period of excess male production. Most energy is stored in the summer or early autumn, the time during which the greatest excess of females is produced. Here I think we obtain decisive evidence that the eggs of winter and early spring which yield an excess of males are eggs which store less material than do the eggs of summer and early autumn which give rise to an excess of females.

It is now necessary to understand that a low storage value in a cell means a high burning capacity—a high metabolism—since the living cell can do only two things with food material that it takes into itself. Such a cell can either burn this material or store it. In case the material is burned the products of burning are liquids or gases (CO_2, water, uric acid) and these escape from the cell without increasing its bulk. In case the material is stored it does increase the mass or size of the cell.

It is evident then that the following out of one of our clues has at least partly resolved the problem of sex difference into the problem of metabolic difference.

In our chemical analyses of the dove's ova several different chemical substances were separated in each analysis. We shall here consider only one of these substances. In the polygons of Fig. 4 we have plotted the average percentage of fat in ova obtained at the various seasons. The point of interest here is that the maximum percentage of fat is attained in the summer or in the early autumn, and this coincides with the period of greatest excess of female production. The ova which most often develop into females are ova in which the relative proportion of fat is notably high. This result is an excellent confirmation of what we observed in the immediately preceding figure; namely, that greatest storage of energy was obtained during summer or early autumn, and that the season of greatest storage is the season of least burning. We can say, therefore, that the results of our 1,200 chemical analyses agree well with the results obtained from some 500 direct determinations of stored energy made in the calorimeter. Both of these results indicate that, in our animals, males arise from ova with higher, females from ova with lower, metabolic rate.

The several facts thus far observed on ring doves have been brought together in Fig. 5. The percentage of females is highest where the storage power is greatest; the proportion of females is

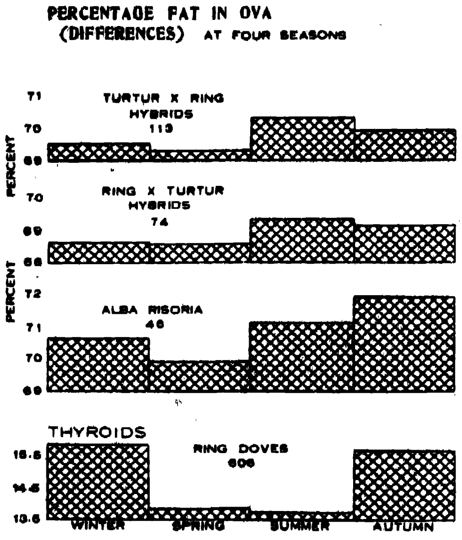


FIG. 4

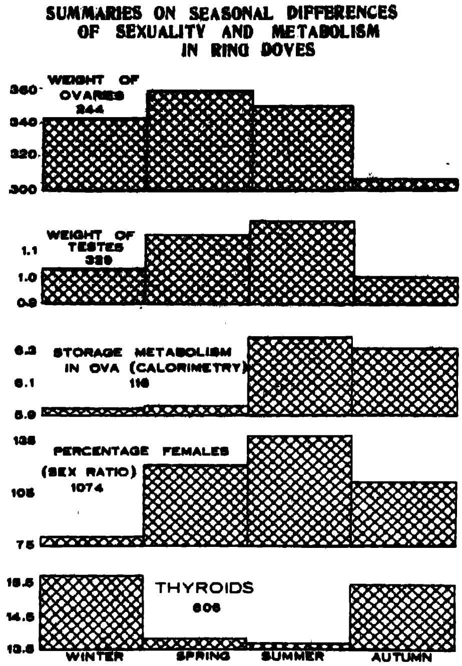


FIG. 5

lowest where the storage power is lowest. Incidentally, it can be observed that the germ glands, testes and ovaries, of these animals undergo a change in size which is quite the reverse of that undergone in the thyroids of these same animals. We thus observe that not only do ova, and the prospective sexuality of these ova, find themselves fluctuating with metabolic changes in the body—as this is indicated by changes in thyroid size—but also the remaining tissues of the germ glands undergo size changes which are comparable in nature. The seasonal changes in sex ratios, which we set out to follow, have now led us into a region of metabolic differences—a region known to be dominated largely by the internal secretions.

Having satisfied ourselves that metabolic distinctions are at the basis of sex-difference in the egg-stage of organisms we wished to know whether these same distinctions persist during embryonic life. In Table 1 you may see the result of our effort to get from dove embryos an answer to this question. We must first state the reason for using this particular method of measurement. The indefinite constantly-changing size of these embryos makes it impossible to measure their metabolism directly. But if male embryos are using oxygen faster than are female embryos, then male embryos should be less injured by abnormally high concentrations of oxygen and more injured by abnormally low concentrations of oxygen than are female embryos. We, therefore, took all of the embryos, that is, all of the fertile eggs, which were produced by our birds during one year and made them undergo from one to five days of their development in atmospheres prepared by us; one series of these atmospheres contained very much oxygen, the other series only about half that of ordinary air.

In these tests a somewhat smaller percentage of males than of females was killed by treatment with "increased oxygen"; and a slightly higher percentage of males survived the "increased oxygen." Further under "decreased

TABLE 1

RESULTS OF SUBJECTING MALE AND FEMALE EMBRYOS TO ALTERED OXYGEN PRESSURES AND LOW TEMPERATURES

NATURE OF TREATMENT	NUMBER OF EMBRYOS	SEXES % KILLED ♂	SEXES % KILLED ♀	SEXES % SURVIVED ♂	SEXES % SURVIVED ♀
COMPLETE DATA					
INCREASED OXYGEN	868	5.6	6.3	94.4	93.7
DECREASED OXYGEN	792	15.2	9.7	84.8	90.3
LOW TEMPERATURE	440	24.3	15.7	75.7	84.3
EXPERIMENTS SHOWING "SEXED" INDIVIDUALS KILLED					
INCREASED OXYGEN	450	13.0	15.1	87.0	84.9
DECREASED OXYGEN	449	29.1	16.8	70.9	83.2
LOW TEMPERATURE	334	33.0	22.3	67.0	77.7

pressures of oxygen'' a higher percentage of males than of females was killed; and under ''decreased pressures of oxygen'' a smaller percentage of males survived. Likewise, low temperatures might be expected to affect sexuality in the same way as does ''decreased oxygen.'' This also proved to be the case. Parts of the same data, taken on a specially rigorous basis, are separately shown on the lower portion of the table. The results there are quite the same. The numbers involved in these experiments are not as large as is desirable; but in this partial test of the question the evidence indicates that the male embryos of doves and pigeons have the higher, female embryos the lower, metabolic rate.

It has recently been shown that very young birds, taken soon after hatching, can still be made to reverse their sex by a single simple surgical operation. This work has been most adequately carried out on young chicks, and by others than myself, though we are also making such operations on young doves. This important result was first obtained four years ago by a French observer who removed the left germ gland—the left ovary—from young chicks soon after hatching. The operated birds were allowed to grow and mature, and it was then found that the right ovary (which is nearly always rudimentary in birds and usually completely degenerates soon after hatching), had here, in each case, continued its growth. Surprisingly enough, in these cases its growth had been continued wholly in the direction of a male germ gland, and indeed a testis which produced sperm was formed. Often, too, on the site of the removed left ovary a second male gland develops.

In these operated animals it was also plain that the internal secretion or hormone of the gland was now that of the male, not that of the female. The comb, plumage and other sex distinctions were now essentially those of a rooster, not those of a hen. Similar results have now been obtained by several workers in various countries and the results are well established. Young birds thus operated usually undergo complete sex-reversal and develop into male adults.

We have very briefly reviewed some of the results which—if they could be completely given—clearly indicate that in the egg-stage, and in early post-embryonic stages, the sex of birds may be reversed. If time permitted two cases of sex-reversal in adult birds could be described.

We have now indicated that during the egg-stage and the embryonic stage, the sexes differ in their rate of metabolism. Naturally, we wish to know whether similar metabolic differences are found in the adult pigeon. This question, among others, is now being studied in our laboratory in collaboration with Professor Benedict, of the Nutrition Laboratory of the Carnegie Institution. At the moment, however, we do not feel prepared to answer this question. Meanwhile, such suitable measurements as are available for the adult human male and female, and for one or two other species of animals, do indicate that the males in these species have the higher metabolism, the difference, in the case of the human, being about 6 per cent. The data at hand seem to warrant the conclusion that males in all life stages have a higher rate of heat production,

energy exchange, or basal metabolism, than have the females of the same species. If this conclusion is supported by further measurements it would seem to be of real importance and of wide application in man's own world. Metabolism in the human is fairly easily influenced by such conditions as habits, diet, occupation and disease; and since sexuality is not an entirely fixed and static thing these metabolic changes are of first importance to the maintenance of normal sexuality. There are several obvious medical and sociological applications of our identification of the relationship of metabolic rate and sex.

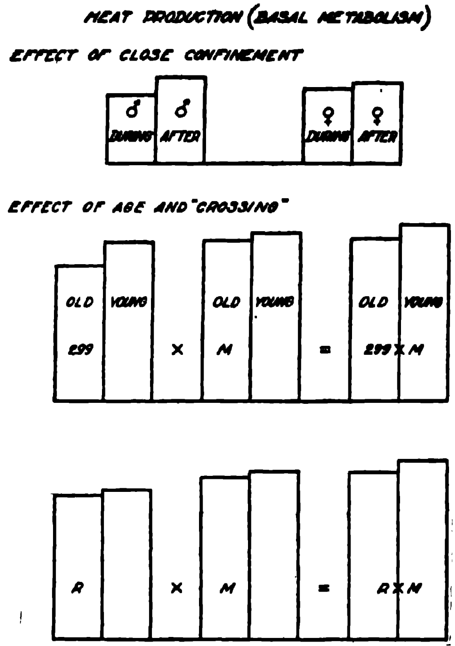


FIG. 6

Our collaborative study with Dr. Benedict has, however, already made it clear that the rate of heat production is notably affected by both the age of the bird and the amount of space in which it is permitted to live. On the latter point we made 60 measurements on 15 doves with the result shown in the uppermost polygons of Fig. 6. You will see that after males have been confined during several weeks in a space too small to permit flight, their metabolism is at a low level. That following four to five weeks of residence in larger cages, which did permit flying, their metabolism was markedly increased. Likewise, the adult females have a lower metabolic rate when under close confinement, and like their male mates they attained a higher rate in the larger cages. But we call your attention particularly to our finding that close confinement, which we must regard as abnormal, affects the metabolism of the male more severely than that of the female. He loses 19.6 per cent. of his normal rate; she loses only 8 per cent. under the same conditions. If this result holds, and can be extended to other species, we shall here have the real reason why Jack builds a house, but remains in it *less*—and *less* agreeably—than does Jane or Jill.

The lower two rows of polygons show two things. First, that young birds of various races of pigeons have a higher metabolism than do the adults of the same races. This difference is so considerable that the age factor here enters largely into the determination of all questions of sex difference or racial difference in metabolic rate. The second and doubtless more important thing shown by these data must next be noted. These polygons contain, so far as I am aware, the first direct and comparable measurements obtained on the metabolic changes which accompany hybridization —or the crossing of races. Note that the measurements made on the two races of the middle polygon indicate that one race has a lower, the other a higher, metabolic rate; but do not fail to observe that in a cross of these two races the resulting offspring have a higher metabolism than that of the higher race entering into the cross. This result applies to both the young and adult hybrids. Also, the two races whose measurements are placed in the lowest row of polygons have unequal metabolic rates; and again,

the hybrids resulting from a cross of these two races have, in both young and adult stages, a higher metabolic rate than that of the higher race entering into their parentage. These four tests doubtless do not provide an adequate basis for saying that this is a universal principle; but these are the first four tests made, and at present our only completed tests of this subject.

These four tests admirably support the view, first derived from entirely different sources, that a wide cross is in itself a means of raising the metabolic rate in all stages of the developing egg and embryo; and that, because the widest crosses raise the metabolic rate most markedly, such fertilizations result in the production of males, and of males only. We are here at the threshold of identifying the long-known increased vigor of hybrids with increased metabolic rate; and since hybridization or mongrelization occurs, and has frequently occurred, in the human family, this finding also would seem to have a considerable application in man's own world.

At the outset of this presentation we noted that frequently repeated egg-laying in doves was associated with change in sex ratios. Later we saw that this resulted in size, chemical and metabolic changes in the ova. It is therefore evident that if we can analyze the several changes which occur at an, or at each, ovulation period we can approach an understanding of the forces which induce or accompany these changes in metabolism and in sex. During the past six or seven years we have thrown some effort into the study of this matter. The results of these studies have been condensed into the form of curves.

The central vertical lines of Fig. 7 indicate the points in time at which an ovum or yolk leaves the ovary of the dove. Time is read on the base-line from left to right. The size or amount of each thing measured is expressed as height from this base-line. You will notice that

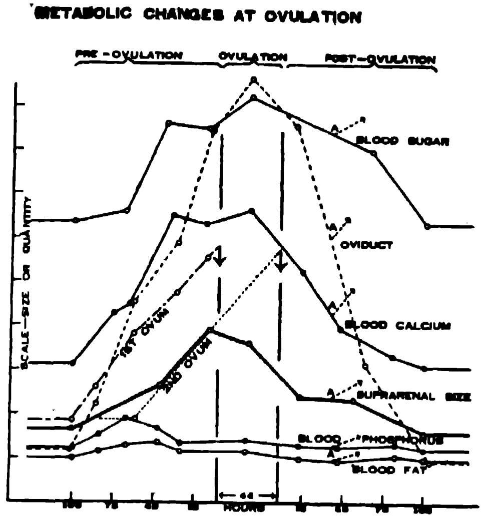


FIG. 7

two ova break away from the ovary—the first, at the left vertical line; the second, occurring 44 hours after the first, at the vertical line on the right. This interval between the two ovulations is spoken of as the "ovulation period." A period of 108 hours preceding the first ovulation we call the pre-ovulation period; a similar period following the ovulation of the second ovum we call the post-ovulation period. These periods have been found to be well-defined and natural things. Our measurements have shown that one of the small eggs of the ovary takes up a new rate of growth, a rate 26 times the former rate, at about 108 hours before it attains its full growth and breaks away from the ovary.

It is also found that the oviduct or uterus, which conducts the egg from the ovary to the exterior, begins to grow at precisely the same time that the first ovum starts its new rate of growth. And indeed we now know that it is one of our regulators of metabolism—namely, a hormone produced within the ovary—that is released into the blood at this time and is thus carried to the walls of the resting, sleeping oviduct, where it makes this organ begin at once a degree of growth

which is almost unheard of elsewhere in adult tissues. Under the stimulus of this internal secretion from the ovary the oviduct increases its size by 1,000 per cent. within a period only a little longer than 108 hours; after another period of 108 hours following the second ovulation the oviduct has again atrophied and shrunk to its normal resting condition. Here it is clear that the growth stimulating hormone which is released from the ovary is produced during a short period of time only, certainly not after the release of the second ovum from the ovary. Incidentally, we have found that the internal secretion of the dove's ovary can be substituted by the same secretion taken from the pig or from the human.

It is well to realize that we here find ourselves in the midst of the many changes brought about by the organs of internal secretion. Ovulation day in the pigeon is indeed mobilization day for the small but powerful army of endocrines.

Your attention is next directed to the curve which describes the size changes observed in the suprarenal glands. At the same time that the first ovum starts its rapid growth, the suprarenals also begin to increase in size—reaching a maximum closely coincident with the time at which the ova leave the ovary. The suprarenal gland—there is one above each kidney—is really composed of two organs of internal secretion, the cortex and the medulla. The cortex produces a hormone which has not yet been isolated, nor even discovered, but it is known to exist and to be essential to life. The medulla secretes a hormone which we commonly know as adrenalin. One of the effects of this hormone is to increase the amount of sugar in the blood. Since our investigation had indicated that both parts of the suprarenal gland had increased in size at this period we wished to know whether they had also increased their function or activity. To determine this, in the case of the medulla, we could find out whether the amount of sugar in the blood increases at this same time. This was studied with the results shown by the curve—the blood sugar is increased by about 20 per cent. This increase, together with the size increase of the medulla itself, supplies evidence that more of the internal secretion which we call adrenalin is being poured into the blood at this period.

The parathyroid glands are also organs of internal secretion, and during the past three or four years it has been learned that the amount of their secretion is very directly related to the amount of calcium in the blood. We have, therefore, measured the blood calcium at various points over this period in order to obtain information as to the part played here by the parathyroids. The result is extraordinarily clear. The normal amount of calcium in the blood is more than doubled at the approach of this particular reproductive period. It returns to normal value at 108 hours after the second ovum is ovulated. This probably means that the hormone of the parathyroids is much increased in anticipation of the release of an ovum from a very distant organ—the ovary.

We have recently measured the amount of fat and phosphorus in the blood at normal periods in the life of the bird, and at the particular period under discussion here. The curves show that both these elements begin to increase in the blood at 108 hours before an ovum is ovulated. Both fat and phosphorus attain maximum values early in the preovulation period, instead of coincidentally with the ovulation period as was found for other constituents of the blood. From this fact we obtain some evidence that a hormone of the ovary is responsible for these two changes in addition to causing the oviduct to enlarge.

We greatly need to know the means by which the ovary is stimulated to begin its work. Within a year Smith, and Zondek, have shown that in mice and rats it is the anterior pituitary body that thus stirs the ovary into maturity and into reproductive action. Our labora-

tory can now report that this result has been extended to the birds. It is thus becoming evident that in all higher animals it is a hormone of the anterior pituitary body that decides the age at which ova and sperm will begin to be formed or matured. We must, therefore, assign the pituitary a share in starting the growth of an ovum, which in turn seems to be the signal of the ovary to the rest of the endocrine company to go into action.

This concludes our examination of the considerable series of changes in the activity of a number of organs of internal secretion, all of which are closely timed to the period of growth and release of an ovum. You will now recall that when the doves were made to ovulate repeatedly the yolk-size was gradually increased, the burning power of the ova was decreased, and an excess of female offspring developed from the ova thus modified. This illustration indicates—at each point provided with an arrow—that under such rapid egg-production the several endocrines responsible for the values plotted here were forced to take up a new—often a maximum—rate of activity instead of lapsing for weeks into a period of comparative rest. We thus discover a part of the basis which repeated ovulations provide for metabolic change and sex change in ova. In obtaining these results our laboratory has had the help of various assistants and collaborators.

I must confess that the data placed on this graph also bring you as nearly as I can hope to take you into the midst of the fine adjustments effected by internal secretions to meet one single phase of reproduction.

We must now, for a few moments, turn to the final division of our subject. We shall see that the recently found prominence of many of the internal secretions in the processes of reproduction makes it possible to consider anew the place which the organs of internal secretion occupy in the scheme of animal evolution.

It is here necessary to direct one preliminary thought to the nervous system. It is a rule that there is no riot within an organism. There are two very complicated and wholly different systems of efficient control. Beyond and around the outlines of the endocrine system which is sketched in Fig. 8 we ask you first to visualize the nervous trunks and networks which may be said to represent the "telegraphic service" of man and bird. Despite the enormous com-

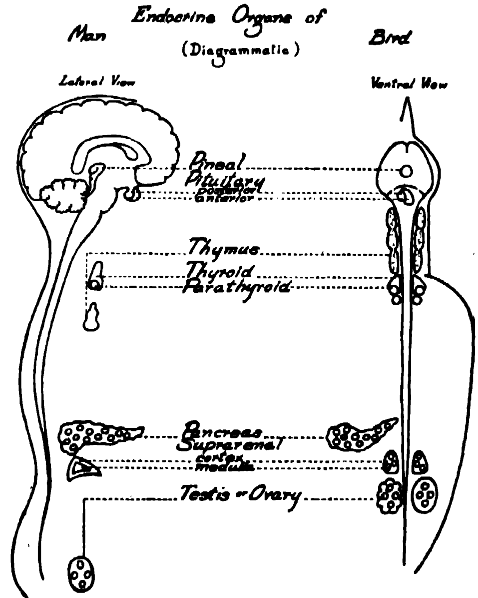


FIG. 8

plexity of this telegraphic system, most of the changes which are connected with reproduction in the bird are found not to be under its control. That control is exercised by the isolated structures whose names and positions are shown in the figure.

The "telegraphic service" is extremely rapid but it has proved entirely inadequate to the needs of so complex an organization as a higher animal. In these animals what we may call a "postal" service has been very exten-

sively developed. This postal, or "chemical messenger" service, is of course the system of internal secretions.

Though a particular organ of internal secretion sometimes looks quite different in the bird and in man, the important chemical substance which it prepares and throws into the blood—that is, its internal secretion—is probably quite the same substance in both man and bird. Except in the case of the pineal—which has not been investigated by us—we have obtained evidence for an equivalent physiological action of all the hormones of the bird and mammal indicated here.

A moment later we shall want to use the fact made clear in Fig. 9. We try to picture quickly the functions of the thymus gland. In our material, which happened to be animals that place albumen, shell-membrane and egg-shell around every egg, it could be shown that the production of these substances is under the control of a thymus hormone which I have called *thymovidin*. In the absence, or practically complete absence, of a thymus it was found that, though the ovary could function normally and could produce ova of normal size, little or no albumen and shell could be secreted. The point needed for our present purpose is that the service performed by this puzzling organ has now been found, and it turns out that its primary function is concerned wholly with the processes of reproduction.

The points at which our various studies have made contact with the internal secretions have, in our opinion, provided a basis for a new conception regarding their place in the general scheme of animal evolution. Table 2 will aid in the presentation of this point. We find that nearly all of the internal secretions are intimately concerned in the processes of reproduction or of sex. And that the only hormones not thus concerned are engaged in the regulation of other *irregular rhythms*. Reproduction is itself a highly rhythmic process.

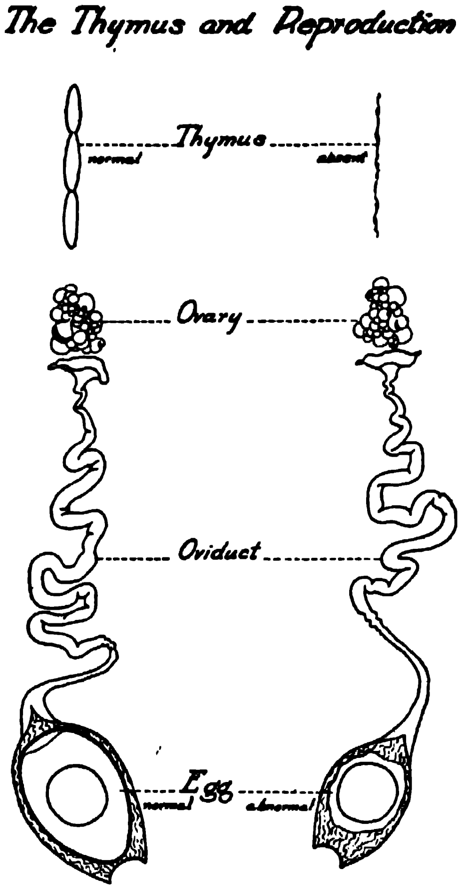


FIG. 9

It thus appears that the "postal," not the "telegraphic," service has been found the efficient method of coordinating irregular rhythms in higher animals.

In the table we give the long list of internal secretions which are now known to be definitely related to reproduction or to sex (those written in parentheses are possibly not true hormones). In another column, at the bottom and to the left, we list those hormones which other investigators have hitherto found no reason for classifying as reproductive hormones. But earlier in this hour two of these three hormones were shown to be concerned in reproduction. You will recall the changes in the blood sugar

TABLE 2

TRUE HORMONES CLASSIFIED WITH REFERENCE TO RHYTHMIC PRODUCTION AND TO THEIR RELATION TO REPRODUCTION AND SEX

METHOD OF SECRETION	UNRELATED TO REPRODUCTION AND SEX	RELATED TO REPRODUCTION OR TO SEX
RHYTHMICALLY SECRETED	(GASTRIN) SECRETIN	(CORPUS LUTEUM) (PLACENTA) (FETAL—FOR ONE SEX)
CONTINUOUSLY, BUT FLUCTUATING	ADRENAL ------→ PARATHYROID ------→ PANCREATIC ------→	OVARY THYROID POSTERIOR PITUITARY TESTIS THYMUS ANTERIOR PITUITARY INTERRENAL CORTEX (PINEAL)

curve (adrenalin), and in the blood calcium curve (parathyroids), at ovulation. We should note that the amount of sugar in the blood is largely the result of the joint action of adrenalin, and of insulin—the hormone of the pancreas. Our laboratory was able to show that injections of insulin made thrice daily effectively prevents the normal increase of blood sugar at ovulation, and also effectively prevents ovulation taking place at all. The only remaining hormones, gastrin and secretin, are concerned in the rhythms of digestion, and they are themselves rhythmically secreted.

We thus learn that nearly all the internal secretions are intimately related to reproduction. This fact has so many impressive associations that I am tempted to suggest that the evolution of the endocrine organs themselves is largely tied up with the elaborate systems of reproduction present in higher animals. It is here only possible to state briefly some conclusions, almost without reference to the evidence. A very simple form of "chemical regulation," much simpler than that involving true hormones, is present in the plants and lowest animals. This form of regulation is older than the nervous system. But a true hormone—a true internal secretion—has not been found in any animal lower than a cray-fish or a leech. The nervous system—both central and sympathetic divisions of it—is present in much lower animals.

The organs of internal secretion are, therefore, of more recent development in the animal series than is the nervous or telegraphic system. The endocrines appeared late, not early, in animal life. It is now, I think, also evident that all of the internal secretions are specially and peculiarly concerned in the regulation of irregular rhythms—and above all in the essential species-preserving rhythms of reproduction. These facts provide some basis for the view that in higher vertebrates and man these organs of internal secretion probably supply the chief source and hope of further evolutional advance. These are the relatively new structures; probably most of them exist in vertebrates only; they are definitely concerned with regulations and correlations; they largely dominate growth and individual development. Where they are present and endowed with such power, how can they escape a large share in further specific and racial advance?

Let us now consider a final item that has a bearing on the remarks just made. Six or seven years ago we decided to test whether—starting chiefly with birds known to have one or another type of reproductive disorder—it was possible to establish races which would perpetuate their abnormalities; and more particularly to see whether we could establish some races with large thyroid glands and other races with hereditarily small thyroids.

Parts of our success in this effort are shown in Fig. 10. You will see that we have readily established some races of ring doves in which we can confidently predict that the offspring will be provided with large, or with small thyroids. During the four or five generations thus far studied the parents of each generation, and the offspring of each generation, have held with fair consistency to a high or to a low level. Success here means that in this material we now have

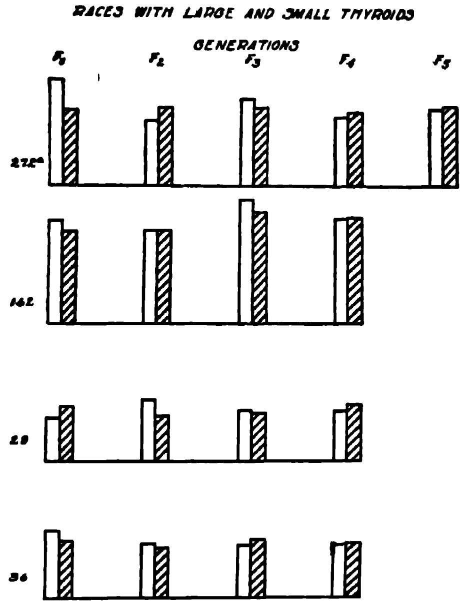


FIG. 10

a chance to learn the perils and advantages to a race of hereditarily large thyroids, or of hereditarily small thyroids—a chance hardly possible in any other known living material. This result also demonstrates that the normal mechanism of heredity can operate in the perpetuation of small changes in the endocrine organs, *i.e.*, in those relatively new organs which in higher animals are taking so large a share in the regulation of growth, of capacity, of health, of reproduction; the same organs whose further modification in these higher animals is, on our view, probably so closely bound up with further evolutional advance in vertebrate animals.

We began our look into the processes of the living world with the observation that two types of reproductive difference, namely, a difference induced by rapidly repeated egg-laying, and a difference effected through fertilization by sperm from a very foreign species, certainly change the sex-ratio and possibly involve a reversal of sexuality. This "possibility" of sex-reversal has been converted into actual demonstration. Sex is reversible, and this is more readily effected in the earlier life-stages. In accomplishing this latter result it has been made altogether probable that maleness and femaleness are really founded upon a difference in metabolic rates. In turn it has been observed that these metabolic differences rest largely upon the internal secretions, and that these secretions are peculiarly and specially related to reproduction. Also, that the internal secretions are relatively recent arrivals in the evolution of animals. Finally, we have seen that new races with size differences in at least one of these endocrine organs—the thyroid—have already been established. May we not say, these races have been created, and that since we are assured of the inheritance of variations of capacity in these regulators and coordinators we here obtain a not-too-distant view of a significant element of our own past and future evolution?

Some of these several problems are by no means fully solved; it is hoped that the work of our laboratory, as this has been discussed here, has contributed a mite toward their solution.

If, in conclusion, this digression of your thought from stars and atoms leaves you with a sense of having entered a nebulous and difficult region, you will be sharing another of my own impressions. The restricted realm of the living, though so near to us—though we are a part of it—is one on which the sunlight, or even moonlight, of definiteness and rigid predictability is scarcely risen. Still, spurred by the notable successes of workers in the more exact sciences, the student of life-processes uses such means as he can to find the rules that apply to the orderly associations of complex molecules which form a living thing. Almost necessarily our efforts lose in precision; but one and another life-process we must measure, since this is the only means we have of arriving at an understanding of ourselves.

HOW IT IS DONE BY THE CHEMIST

By Professor D. B. KEYES

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INDUSTRIAL chemical research has been the subject of much conversation in recent years. Much has been written about its importance and much about its results but little has been said about how it is done. The public still believe it is an art acquired by few. The great research genius of chemical industry is still believed to be a rather impossible creature who spends his hours in profound thought among his test tubes and weird machines. By secluding himself in his laboratory, concentrating entirely upon his problem for a period of many years, he is thus able to have ideas far above the common herd and thereby acquires great fame for himself and vast financial profit for others. Nothing could be further from the truth.

To-day, industrial chemical research has been systematized and standardized. Any desired result can be obtained if sufficient men, money and time are available. The element of luck has been reduced to a minimum. Fortune still dictates the quantity of energy necessary to acquire success but that is all. Fortune is the catalizer of unknown positive or negative value.

On the other hand, romance and interest has not fled from this field of work; quite the contrary. To-day the joy of accomplishment in industrial chemical research can be had by the many and not as formerly, by the few. It is the delightful purpose of this article to prove this statement.

One of the most interesting and most common types of research in our chemical industries is the development of a new and more efficient process to produce an old and well known product. The work on such a problem has been standardized. The order of procedure is as follows:

1. A thorough review of the literature.
2. A selection from this review of the best method so far developed for the particular conditions required by the problem.
3. A listing of all the factors involved in the reaction or method.
4. A listing of all methods of varying each factor.
5. A selection of the factor which shall be varied first and the method of varying it.

A rather remarkable piece of work[1] was done some years ago which will illustrate this standardized method of procedure. Immediately after the Armistice a certain chemical company found itself with large stocks and large capacity to produce ethyl alcohol and dilute (10 per cent.) acetic acid and with no adequate market for either. It was thought that ethyl acetate formed by the reaction of alcohol and acetic acid might be a profitable compound to manufacture. A thorough review of the literature was made. The text-books stated quite conclusively that ethyl acetate can be made only with concentrated acetic acid, absolute alcohol and appreciable amounts of sulfuric acid, the catalyst. Even then the yields were rather low. The process selected was naturally as follows:

$$\text{Acetic acid } (10\%) + \text{ethyl alcohol } (95\%) \xrightarrow{H_2SO_4} \text{ethyl acetate} + \text{water.}$$

[1] Covered by U. S. and Foreign Patents.

From an economic standpoint either this reaction would be made to work or the entire development as far as this plant was concerned would have to be abandoned.

The list of factors were evidently as follows—pressure, temperature, catalyst, acetic acid, ethyl alcohol, ethyl acetate and water.

Pressure and temperature could be varied over wide ranges. The remaining factors could be changed both from a physical and chemical standpoint.

For the preliminary experiments in the laboratory change in concentration of the sulfuric acid was tried. This was done for the simple reason that it was easier than finding a new catalyst of different chemical composition. The results were gratifying. It was found that only a relatively small concentration of sulfuric acid was necessary to bring the reaction to equilibrium.

A new problem immediately presented itself. How could one disturb the equilibrium and obtain 100 per cent. yields. It is well known to those who are familiar with equilibrium reactions that an increase in concentration of the raw materials will disturb the equilibrium in the right direction. It was also well known that a lowering of the concentration of the final products would help produce the desired results. It was, or rather is now, quite obvious, what was the proper selection of factors and variation that should be tried first.

A mixture was made consisting of ethyl alcohol in considerable excess, dilute acetic acid and the proper amount of sulfuric acid. This mixture was passed into the side of a fractionating column. It was found that water and the sulfuric acid came out at the bottom, while a ternary mixture of ethyl acetate, alcohol, and water came out the top. The ternary mixture had a higher vapor pressure than the water and sulfuric acid mixture. As those facts were known the results could have been predicted. It should be noted that no acetic acid appeared; it was entirely consumed in the reaction. On the basis of acetic acid, the yield was 100 per cent. This was brought about by increasing the concentration of ethyl alcohol in the original mix, and permitting the fractionating column to reduce the concentration of the products ethyl acetate and water by removing them from the reaction zone. It was too difficult to increase the concentration of acetic acid, so it was not attempted. The fractionating column also reduced the alcohol concentration which would have been detrimental had not a large excess of alcohol been added in the beginning.

Still another serious problem presented itself. The yield was 100 per cent., but the product was a mixture and not pure ethyl acetate as desired. It is customary to fractionate such a mixture and obtain a pure product. The three however were found to form a constant boiling ternary mixture, so simple fractionation was out of the question. The physical reaction desired might be stated as follows:

(Ethyl acetate, alcohol, water) mixture ⟶ ethyl acetate + (alcohol, water) mixture.

It is common to add salt water to such a mixture. In this mixture water alone was all that was necessary. Two liquid layers appeared on the addition of an excess of water. The upper layer contained most of the ethyl acetate and small quantities of alcohol and water. Pure ethyl acetate was obtained by simple fractionation of this layer.

This was, of course not all of the features of this remarkable development. It covers, however, the most important features. It should be noted how closely the development followed the standardized plan of attack. No attempt has been made to under-estimate the intellect, ability and knowledge involved. It

is desired only to show the sound logic and common sense used in the undertaking, and to point out that this very worth while research was successful not because of any wild dreams and very fortunate hunches on the part of the inventor.

There is another type of industrial chemical research which is extremely attractive, but not so common as the one just mentioned. It is the development of a new and more efficient chemical product to take the place of an old product. The new product is often damned by the noun "substitute" or the adjective "artificial." Rayon which is replacing silk is such a product. Phenol-formaldehyde plastics (Bakelite and Redmanol) and the tungsten filament are other examples. This research, difficult as it is, has a suggested plan of attack. One of these proposed plans is as follows:

1. A list of the faults of the old product.
2. A list of similar products not used for the same purpose.
3. A selection from list No. 2 of the most suitable product.
4. Modification of this product to eliminate faults.

It has been known for some time that tincture of iodine is a highly unsatisfactory household antiseptic when applied to open wounds. The content of iodine (7 per cent.) is far too great. In many cases it probably does more harm than good, because of its tendency to attack the living tissue. The solvent, alcohol, (concentrated) is not the sensible thing to put in a cut any more than a red hot iron. Furthermore, tincture of iodine in a bottle with a cork or rubber stopper is not always safe to carry in one's vest pocket or traveling bag. In brief, tincture of iodine as a household antiseptic has its faults.

Among the many compounds of iodine that appear on the market might be mentioned potassium iodate. This product probably has no real antiseptic powers but free iodine does. It has been known for some time that weak acids will liberate free iodine from a mixture of potassium iodide and iodate. It was therefore believed that a dry powdered mixture of potassium iodide, potassium iodate, and an acid salt might be used to replace tincture of iodine. Such a mixture[2] was made. The results were very gratifying. The new product was easily soluble in warm water and quickly released its iodine. The resulting solutions were found to have great bactericidal action on the common bacteria. No irritation caused by a reaction with living tissue was noticeable. The solution could be varied over wide concentration ranges. Even dilute solutions that could be used as a gargle with comfort proved to be efficient as an antiseptic. Furthermore, the dry powder could be carried in perfect safety in pockets or in a bag. The package could be a glass bottle, an aluminum tube, or a pasteboard box.

Here again knowledge, common sense, and a logical plan of attack proved successful and developed a product that should mean much to mankind.

Still another type of research is common in chemical industries. It is the development of a new machine for an old purpose. Many of the fantastic developments since the war have been of this type. The profits of such developments are usually large. This type is little understood and strange to say the method commonly used is the simplest and one of the easiest to follow. It might be outlined as follows:

1. A list of all the basic requirements of the process.
2. A list of apparatus used in other industries for a similar purpose.
3. A selection of the apparatus which will most nearly satisfy the requirements of the process.

[2] Covered by U. S. and foreign patents.

4. Modification of this apparatus to meet the special conditions.

A very interesting case is the recent methyl alcohol development in Europe. Here the method shown above was worked backwards. The famous Haber equipment for fixing atmospheric nitrogen lay idle after the war. The capacity was far beyond the peace time needs. Some brilliant experimenters conceived the idea that it might be used for some other reaction. Carbon monoxide and hydrogen (Water Gas) were cheap and plentiful so they were used as the raw materials in an experimental run. Methyl alcohol appeared as one of the products, probably, much to the surprise of every one. No particular attention was paid to the catalyst in this first run. The Haber equipment was capable of developing high pressures and high temperatures at the same time. This was its unique feature. It was well known that carbon monoxide can not be reduced with hydrogen at ordinary pressures and temperatures. Therefore, it was rightly concluded that with ordinary catalysts, high pressure and high temperatures were basic requirements of the process.

The romantic tale does not end here however. An American concern has started the production of methyl alcohol from methane (Natural Gas) by partial oxidation with air. This was done by utilizing a standard equipment formerly used for another purpose. The design and operation was modified to meet the new conditions. Methyl alcohol can be made cheaper, in all probability, by this process. This means that once again the high pressure, high temperature equipment will become idle and the research workers will be faced with the problem of finding new raw materials. Fortunately there are several chemical elements and compounds left to try out.

About twenty years passed by before we realized that the X-ray machine could be used for anything other than locating the tack little Cuthbert had swallowed.[8] To-day whenever we want to know something about the internal structure of anything, we use the X-ray. Why, because we need a ray that will go through and not be reflected from the surface. It makes no difference whether the material is butter or steel. The basic requirements of our process are satisfied by the X-ray machine.

Oftentimes this type of research is relatively simple. Our great motor fuel industry for many years confined its development solely to increased production. Money spent on producing increased yields and higher grade products did not produce dividends equal to those produced by the same investment in additional production. To-day the tables are turned. Fractionating columns used by the alcohol industry for the last thirty years are now employed in the petroleum refineries. Certain modifications were necessary. Whenever the basic requirements of the process and the function of the fractionating columns were thoroughly understood and appreciated, success was immediate and certain.

An interesting development of this kind has occurred in the natural gasoline industry. In this industry gasoline is obtained from natural gas by compression, absorption, or adsorption. The crude product contains not only the desirable higher boiling hydrocarbons (butane and up) but also the low boiling, volatile, and undesirable hydrocarbons (propane, ethane, and methane). This volatile constituent is removed by "weathering." This is a simple distillation in a still that no self-respecting bootlegger would think of using. The result of using such an apparatus is quite evi-

[8] This hysteresis of the human mind has been pointed out by S. C. Gilfillan in an excellent article entitled "Who Invented It," published in the Dec., 1927, issue of THE SCIENTIFIC MONTHLY.

dent to any one familiar with the basic principles of fractionation. The volatile material is removed and with it appreciable amounts of the less volatile and desirable material. The simple substitution of a fractionating column for the eighteenth century still has given in one case a 45 per cent. increase in yield.

Sometimes the proper selection of apparatus is difficult and sometimes it is a matter of chance. An excellent illustration of the latter is given in the story of the famous New Englander who sent a cargo of warming pans to the Tropics, and the ingenious native found them useful for concentrating sugar syrups.

Often the necessary modifications of the machine are not apparent. There is a story told of Mr. Edison in the early days that will illustrate this point. Mr. Edison was adapting the horse shoe magnet to the electric motor. The magnet was placed vertically with the armature at the bottom between the poles. A heavy iron base was necessary, but this produced an iron connection between the poles. The lines of force were promptly shunted away from the armature and the machine would not work. Mr. Edison and his colleagues worked long hours to devise a non-conducting material to be placed between the poles and the iron base. A fairly satisfactory material was devised and several of these machines were sold. A few years ago some university laboratories still had this model on display. A master mind, the story does not include his name, finally pointed out to Mr. Edison that the problem could be solved by merely turning the machine upside down. No metal connection between the poles was required as the iron base was on the other end where it did no harm.

Many more illustrations of this fascinating type of research could be given. The most interesting and perhaps most far reaching in their significance are developments of this type that are underway at the present moment. They are, however, in that delicate state that premature exposure might prove fatal. It is hoped that the reader will be content with the evidence already submitted.

SCIENCE AND CONDUCT

By Professor A. W. MEYER

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FORTY years ago so sound a writer as Matthew Arnold joined in the lament over the eclipse of the humanities by science. Although he uttered some words of reassurance these must have been forgotten, for even to-day there are those who tremble lest "wisdom and joy die in a test-tube."

Since Arnold, of Rugby, declared that "Rather than have physical science the principal thing in my son's mind, I would gladly have him think that the sun went round the earth, and that the stars were so many spangles set in the bright, blue firmament," Matthew's attitude need not surprise us, and he who has not cast suspicious glances at science in our own day has an even-tempered soul indeed. There are even those who profess to believe that science is a curse rather than a blessing, and I may recall the remark of a scholarly friend who declared that he was not aware that he owed anything to science except the electric light. Taken as a confession this might pass in silence as it did, but taken as a valuation of the service of science to him it was benighted indeed.

I am certain that such verdicts as these on science do not rest on any lack of heart, but on a lack of knowledge of modern life and on a misconception of what science really is. In the minds of these good people, science is supposed to be a collection of so-called dead facts, and minister only to man's lower wants. To them the scientist merely is a "fact peddler." Even a very liberal contemporary clergyman thinks that "all organisms are to him (the scientist) nothing but objects for observation and report," and some scientists regard science merely as classified knowledge. If it be the latter, then it is mummified and ready to be labeled and exhibited in museums, side by side with other mummies and fossils. Since Berkeley regarded the abundance of fossils as the possible cause of scurvy and hypochondria among the British people, I am tempted to add that such a view as this of science should give others than the British, hypochondria.

A mere collection of facts no more constitutes science than a collection of pigments constitutes painting. Facts are only the materials upon which and with which the mind of the scientist, as that of the humanist, works. The temple of science is, to be sure, constructed with facts as foundation units, but no building can stand without mortar and none ever was shapen without the directing mind of an architect. Separate pigments alone can not make a Sistine Madonna and in the rearing of the temple of science the play of the imagination also had a large part. It too is the product of creative thought and here is one place where science and art meet.

We judge the rôle of art by the influence of the final product, and not from the effect of the separate materials, and that also must be our attitude toward science. The scientist too is a poet —a creator—and breathes life into the facts which he discovers. He does not kill live facts, but discovers so-called dead facts and makes them live. He also has his ideal world and if poetry has a soul, then science too has one and who would deny that science has in the past set the soul of men aflame and that it shall do so in the future. The starry

sky has not lost, but gained in grandeur through the hand of science. Although "astronomy has decentralized the world" it also has "revealed to us, as by an angel's hand, the scope of the heavens and the import of the stars." . . . "The more a man knows, therefore, the more full of wonder he finds the world." Were this not so, then the ox in the stall would stand in awe and wonder at the universe as much as man.

Science does not, in the words of Chateaubriand, "ask man to live with a full heart in an empty world." It does not destroy mysteries but fills the world with meaning. It is not a hod carrier, but a torch bearer. "Scientific knowledge teaches us to hear the innermost soul of things vibrating in unison with our own souls, and it is just this which enables us to understand them and to absorb into our Ego the revelation of their true being." According to Wilbois "Scientific life is then the first step towards loftier spontaneity; invention is fulfilled in virtue." Science can not know beyond this life, but there is nothing to prevent it from looking beyond. For it too "Omnia exeunt in mysterium."

In the solution of every scientific problem many others are raised. Every new fact that is revealed suggests new relations and the existence of other facts not dreamt of before. Hitherto unknown facts and relationships are constantly being revealed and so the mystery always broadens and deepens. A geocentric universe held the cramped thoughts of men until a heliocentric universe displaced it, and this in its turn has given place to a truly staggering conception until infinity and eternity both stare us in the face.

Science is daily making discoveries both in the direction of the infinitely small and the infinitely great until, as Abbott wrote, "Not the awful immensity, but the infinite complexity of the universe compels thoughtful men to feel that there must be a creative intelligence behind it all." Although I do not feel that complexity more than anything else should compel men to believe in the existence of a Supreme Being, I never have felt that science compelled any one to abandon such a belief. As Aliotta says, "The rationality which science postulates in nature leads us to Divine Consciousness, as a necessary complement, because a reason, an objective system of concepts and ideal relations, without consciousness, is something we can not understand."

It is heartening that theologians have caught the larger meaning of science. The dean of St. Paul's, for example, wrote recently: "Science is not, as some have erroneously supposed, a description of fact without valuation. Such a description would be utterly impossible, and it should be superfluous to point out how widely the world, as known to science, differs from the final analysis of material objects into electrons or protons." The scientist must evaluate facts in determining their relationship and in trying to determine their significance in the world scheme. Whether beings are normal or abnormal is a vital matter to him, and organisms are more to him than objects for observation and report, if by that is meant that he merely is an amanuensis for nature, an automaton.

I am not, to be sure, using the word science in the narrow, antediluvian, but in the broad, modern sense. The rough grouping of physical, biological and social sciences serves my purpose very well, provided it is not forgotten that the history, the development, and the philosophy of each are integral parts of them. So considered science has an inner, as well as an outer, content, and that, to be sure, it had from its beginning. Science in this sense assuredly does more than "turn our spindles, haul our goods, and coin our money," and perchance relieve us of daily physical distress in the later days of life.

The most obvious surely are not the most ennobling effects of science. It has made contributions, not only to our material needs, but to our higher culture and, I confess, I have often envied critics of science the sweep and finality, as well as the assurance, with which their verdicts concerning it have been delivered. They prompt one to counsel, "Let us fold our tents and steal away, for there is nothing more to do. All is settled now." I believe that the explanation for this confident derogatory attitude lies in the fact that some of these good people have not even realized the modest hope of Matthew Arnold, who avowed that he might care to know as much science as "he could conveniently carry." However ample in other respects, Arnold's conveniences apparently were rather limited in this regard.

In spite of the oft-cited confession of Darwin, devotion to science does not in itself imply indifference to literature, music and other fine arts or blind one to the fruits of friendly intercourse or to the great rôle of religion as a social force and a personal guide and comfort. The scientist, as the artist, may be preoccupied with the field of his choice to the neglect of other interests, but he does this not because he is a scientist but because he is human. He probably is no greater an offender in this respect than the humanist, and it should not be forgotten that science as well as literature, the fine arts and music also is a product of the human spirit.

In the face of de Garmo's warning, in the days of my young manhood, that "we have labor for our pains if we look for the embodiment of ethical truths in nature and natural science," I made bold to look for them long ago. Such pronouncements as de Garmo's regard the study of science merely as a study of dead things, and exclude the social sciences. They overlook the fact that nature includes what is living as well as what is dead and that man, himself, always has belonged to the study of science. "The end of science is not to attain to abstract laws, but rather to comprehend the facts of experience in the light of laws." . . . "The essential thing is not to reproach scientific knowledge with the abstraction which is a practical drawback that can not be eliminated in the realm of philosophy" even.

The mechanistic or any other one-sided conception of nature is only a partial view, and no matter how great the change wrought by the scientific method no one can claim that a completer view of nature would be hampering to future progress. Mathematical formulae and physico-chemical laws are inadequate in biology. To try to reduce everything to a mathematical basis well may reveal many undreamt of relationships to us, but it does not seem that it ever can give any one a full interpretation of living things for it begins with the assumption that life can be expressed in a formula. As Maxwell wrote: "There are many things in heaven and earth which, by the selection required for the application of scientific methods, have been excluded from our philosophy." Nature assuredly is not merely what a mathematical formula can state, but also what I can experience and can not say in words. The world of the mechanist, like that of the traditional religionist, is a make-believe world. Neither is real.

Any one familiar with the history of science realizes that there has been a steady though gradual expansion of its domain. In the absence of scientific knowledge man had to depend wholly upon divinities for protection against famine, pestilence, overpopulation and war. He has learned better regarding the first two, and must do better about the last. Against famine, pestilence and overpopulation only science can win the battle, and when the evils and woes of strife will become sufficiently known, the hearts of men will be turned toward peace. The bare facts will displace the

gods also here just as soon as men fully realize the futility and comprehend the tragedy of strife.

I know full well that Pallas Athene was endowed with a sword as well as an owl, but that does not excuse educated men from declaring that "the bulk of science and research only require accuracy of observation, careful experiment and logical deduction, and a rascal can perform those requirements as well as an honest man." In comment I should question the word only, and then add that a rascal also can read the Bible, can pray and preach, and indeed not infrequently does so, to very respectable people. Yes, a rascal can do that, but a fool can not. A high morality does not exist among degenerates. A developed intellect is essential to good conduct. Not only that, but knowledge is necessary for right action in many things, for no matter how well developed an intellect may be, without the requisite knowledge no one can realize the probable consequences of his acts. Good intentions alone will not necessarily prevent any one from committing anti-social or unmoral acts.

It is said that only saints can lead a truly religious life, and I am certain that only sages can lead a truly scientific life. The bearings of modern science upon life are so manifold that the most conscientious will find themselves again and again unwittingly acting to the detriment of their fellows. Every one of us has had abundant occasion to say "I meant to do the right thing, but I did not know." This, it seems to me, is a juster interpretation of many errors in conduct on the part of decent people than to hold that they knew what was right but did not do it.

I know that it is customary to speak of this as a scientific age, and to regard ours as a scientific civilization, but that is a slander upon, as well as a tribute to science, for our age is scientific no more than it is Christian. We are not educated scientifically even. A study of the courses taken by students at one of our foremost universities, for example, showed that only about one tenth of their time was spent on natural science in their entire progress from the kindergarten to the end of college life. Were modern life not characterized by the lack rather than by the predominance of use of the scientific method, quackery could not find a multitude of patrons among all classes. We do not use but misuse science. In the words of Soddy, "We have fooled with the achievements of science." Were science really heeded, some of the most perplexing and distressing social problems would have found a better solution long ago.

It has often seemed to me that it will be far more difficult to establish a scientific civilization than a religious one. Belief spreads easily, even when it concerns scientific things. It does not take long to believe that I-On-A-Co cures all ills, but it would take long indeed to prove it! Knowledge comes far slower than belief, for it is the result of individual effort, of toil. It may have been this which caused Stevenson to say that the lamp of science smells terribly of oil, but it frequently is forgotten that he also added that its light shines very brightly.

Science is slow and halting and can not hurry. It must be circumspect. Dogma, being ready-made, is always at hand. It knows none of the impediments of science. Science encourages the suspension of judgment, not the abdication of it. It inculcates a judicial attitude, and by revealing man's place in the world, teaches him humility and that should make for tolerance. It does not, it is true, invariably effect these things, but surely that is not surprising, for the far older humanities, and the still older religions, also have failed to do so. They too could not wholly overcome human frailty.

I know that the open-mindedness,

freedom from personal bias, reverence and humility, etc., which science tends to cultivate, can only help to tell us what to do. They do not tell us to do it. They do not embody the categorical imperative. But let it not be forgotten that science declares that no one can escape the inevitable and that every one violates the laws of nature at his peril. This is what the decalogue tells but I may violate the latter and supposedly be damned for it in a conjectural future life, while if I violate a law of nature I will be damned for it here and now.

Science supplies motives for right action and assures a better judgment. The conception of harmony and fitness in nature also tends to develop the moral sense—at least indirectly—and a study of living things, in many scales of life, does this directly. For science reveals the effects of acts upon the individual, as well as upon the community of beings. It shows how individual and community welfare are interrelated and achieved in nature and that includes man. It shows that happiness depends upon conduct in conformity with law—conduct that takes cognizance of group, as well as of individual, interests. That the only great concerns are community concerns, "the only great sorrows, public sorrows," and that should make for unselfishness. It encourages integrity and a love of and a loyalty to truth, wholly regardless of the consequences. Even a critical writer such as Webb admits that "it is beyond question that scientific research is a school of many virtues, including some which religion in general and Christianity in particular, have not promoted," and Fosdick even declared that "There is such a thing as the religion of science, where men at all costs and hazards live for the love of truth."

Two tenets of physical science, the indestructibility of matter and energy, imply and constantly remind one of the eternal. Instead of a world which was created a few thousand years before Christ, and whose ending often was confidently anticipated in the past, science has given us a universe whose extent exceeds human comprehension, and whose age must be reckoned in countless eons. This in itself should arouse feelings of awe and wonder impossible without such conceptions, else an ox might experience them just as well as man.

Science, too, has its heroes and its heroism, and the spirit of science is well exemplified in its great men. I can not imagine a better school for morals than the story of the development of science and its rôle in past civilization. Ethical implications lie on all sides. As Aliotta well said, "Science is not the night in which all cows are black." The teachings of science are not merely negative. They show that folly leads to ruin, that disuse leads to atrophy, and these are ethical principles of both philosophy and religion. The parable of the talents is embodied also in science and the teachings of science and the ethics of Christianity coincide in many respects. This was pointed out by Huxley when he wrote, "Science seems to me to teach in the highest and strongest manner the great truth which is embodied in the Christian conception of entire surrender to the will of God. Sit down before the fact as a little child, be prepared to give up every preconceived notion, follow humbly wherever and to whatever abyss Nature leads, or you shall learn nothing. I have only begun to learn content and peace of mind since I have resolved at all risks to do this."

We call acts immoral because of the misery they cause, and moral if they promote the common good. Science alone can reveal the misery or the good to us or to others. Experience, to be sure, can do so, but its sphere necessarily is restricted to the individual, and we must learn to depend more upon the experience of others or history will teach us nothing. Our ideas of morals, as our gods, are self-created and changing.

Both are the product of human evolution and he was a wise man indeed who said that one knows a people by its gods. We evolved our morals and fashioned our anthropomorphic gods to suit ourselves. Neither was imposed upon us from without, although in so far as our morals are based upon the feeling of affection, of concern for others, they are instinctive in a sense, and in so far as the feeling of affection is not instinctive, it can arise only upon the basis of knowledge.

The fact that science has revealed the existence of strife among living things has often been held against it, but it also has revealed the presence of altruism and the prevalence of harmony and unity in the universe. However, as long as strife exists it is well that humanity should know about it. Every one knows that a fool's paradise can not endure, and only a fleeting happiness can be secured by thinking one's self in heaven when one actually is elsewhere. Moreover, it may be recalled that Spencer argued that altruism could never have arisen but for the existence of strife. That in order that half of mankind might be altruistic, the other half must be non-altruistic.

Science deals with forces within, as well as with those without, the individual. It demonstrates that there is no escape from the eternal forces of nature, and that collision with them means suffering and disaster, that happiness, on the other hand, lies in obedience to law. By demonstrating the existence of natural law in the physical world, it has led to the conception of natural law in the spiritual world, and by revealing a universal law and order among things, it has revealed harmony in the world and set its face like flint against lawlessness of all kinds.

The idea of kinship in nature was established firmly by science, and this idea can not help but enforce the Christian teaching of human brotherhood. Instead of teaching that man arose in perfection and lost it, and that he can look forward to none but evil days, science encourages men to take heart and to try to achieve a better day on earth. By giving him a better comprehension of his surroundings it has made man feel more at home in an inhospitable universe. As Wyatt put it, "It is science, and science alone, which enables the human mind to pierce the veil covering the inner spirit of nature, and to see the glory behind the apparent shame." It reminds him that he is not necessarily born good and free and happy, but that some of us are born short and others with evil impulses. It alone can reveal the relation between personality and life work, between the physiologic inheritance of men and their personal conduct and social influence.

It has shown plainly that man's lowly origin need not keep him from aspiring to perfection and it does not negate the noble command of the great Florentine:

> Know ye the heavenly seed from which ye came,
> Not for the lusts of beasts were ye compacted
> But that your minds and hearts be set to flame.

However far it may be from its final goal, science bids fair to consider all things in the heavens and on earth, not excluding even the thoughts, the dreams and the hopes of men. As Aliotta has well said, "the scientist does not confine himself to the world of nature, but insists rightly upon submitting even religion and religious feeling to scrutiny." It is useless to put up "No admission" signs. The activity of scientists is self-directed and also engaged in finding schemes which may serve as a guide in the complexity of the phenomena of experience. . . . Scientific truths are admitted by us that we may recognize that they are means for attainment of our ethical ends. Thus religion and science are reconciled in the common origin, which is always an act of pure will." If this be true then science too makes for a broad and liberal outlook

of life and develops a sense of value which James, I believe, regarded as the aim of culture. It can not help but cultivate the critical sense which Arnold regarded as the main value of the study of literature and it constantly is revealing the true and the beautiful, and stimulates the esthetic. I do not, to be sure, hold that all branches of science do these things to the same extent, or that they have this effect upon all who enjoy its fruits. It is a universal solvent of our perplexities no more than art or religion, but it surely gives us a fuller grasp of ourselves and of the world in which we live.

This higher rôle of science is what Berthelot called ideal science. It rises above mere observation and empiricism, and no matter what individual scientists may have thought, science always has had a higher content of value as well as a lower content of fact. It not only reveals the outer world to man, but reveals man to himself. Yet, in spite of all this, Russell confesses that he is still doubtful whether science will prove to be a blessing or a curse to humanity, and a faddist and scoffer, like Coleridge, wrote, in all seriousness, "The motor car and the bicycle then are the two undoubtedly beneficient inventions that science has conferred upon a world which it has otherwise physically defaced and ruined, and morally degraded and defiled past hope, past cure."

Although Russell seems so doubtful about the rôle and the future of science, he sees an only possibility for betterment in a world government established by force in order "to preserve a scientific civilization," which if "once realized will gradually give rise to the other conditions of a tolerable existence." Here, then, is a philosopher who maintains that science has had little influence on our institutions and who as yet is doubtful whether it is a blessing or a curse, but who nevertheless proposes the use of force to establish this so-called doubtful scientific civilization! Even if this civilization merely is tolerable, it must be confessed that other forces have failed to accomplish a better result; and if we are but "bundles of passions and instincts," as Russell maintains, it is clear that nothing approximating a scientific civilization ever can be established, for science rests on reason, not on blind passion and heartless instinct.

As long as we regarded all diseases as visited upon us by the gods, we did not need to trouble ourselves about sanitation and its many serious problems and effects. As long as we regarded the insane as possessed of the devil, we could with clear consciences deride and stone them on the streets and have them perform for our amusement at wedding feasts. It required much earnest search before we learned that a dermoid of the ovary did not convict the unfortunate possessor—sometimes a mere child—of illegitimate sexual relations. Think of the brutal treatment and bitter persecution of luckless little girls in the name of religion and morals for an accident of development in prenatal life! The important thing is not that progress toward better things has been slow in these matters, but that it came solely by the aid of science, and what we formerly regarded or now hold to be right or wrong depends wholly upon the facts at our command.

Science does not deaden but quicken our moral judgments. This has been true, not only in the above, but also in a multitude of other things. It is exactly in the many complicated relations of everyday life that the facts revealed by science help to determine our conduct. Whether it be a personal question such as divorce because of incompatibility; of venereal diseases in the adult or the newborn; the presence of typhoid germs in milk; the disastrous breaking of a dam; the explosion of an oil truck; the occurrence of pellagra, scurvy or beriberi in our asylums; the punishment

of crime; the question of drug addiction; the marriage of near relatives or defectives; or political questions such as matters of government and international relations; in all these things the question of justice and right must be determined upon the basis of the facts. Our conduct must be determined by knowledge and reason, not only by feeling. Inspiration fails us and religion and ethics are helpless without a knowledge of the facts. Can any one, for example, imagine the difference to the world if peace treaties had been made on such a basis instead of that of feeling!

No one could lead an even approximately correct life to-day without the help of science. It gives us wider knowledge of our work-a-day world; and as morality is based largely upon reason and knowledge, it follows that science must remain one of the greatest of influences toward right action. Since it gives us a knowledge of ourselves and also of others, it must tend to increase, not to decrease affection, and in this way further influence morality. As long as I do not know that a certain act is hurtful to myself or to others, I will not be saved, except by painful experience or happy accident, of committing unmoral acts. But I can only learn of what is hurtful from knowledge and experience.

It is strange that Webb held that science "subtracts from the ethical standards it surveys," while stating that "the damaging criticism of men of science during the last two hundred years against the old rational theology, with its proofs of the existence of God, have antiquated a type of view which appeared reasonable to some of the greatest minds of an earlier age. . . . The scheme, which satisfied the imagination of Augustine and of Dante, of Milton and Pascal, it is not indeed possible for us to accept as more than a symbolic picture. It is too late in the day to rehabilitate the credit of the 'Book of Genesis' as a faithful record of the origin of the world and of mankind, or that of the New Testament eschatology as an accurate forecast of their future destiny." Dean Inge—and other theologians—also declared that "the discovery that the earth, instead of being the center of the universe, like a dish with a cover over it, is a planet revolving around the sun, which, itself, is only one of millions of stars, has torn into shreds the Christian map of the universe," and that "science has made the belief in a geographical heaven and hell impossible, or at least very difficult." Hence science apparently is doing exactly what James hoped for when he said that what most men need "is that their faiths should be broken up and ventilated, that the northwest wind of science should get into them and blow their sickness and barbarism away." Indeed, who can fail to admire the courage and integrity of Mill in declaring: "I will call no being good who is not what I mean by good, when I apply the word to my fellow creatures, and if there is a God who can send me to his hell for not calling him so, to hell I go."

Science is helping to make new creeds long before the time referred to by Morley when he wrote, "Science, when she has accomplished all her triumphs in her order, will still have to go back, when the time comes, to assist in building up a new creed by which man can live." Indeed, this new creed is being built daily, although few scientists would go as far as Eliot when he declared that "There would be no perceptible influence on the morals of the race if Hell were quenched and Heaven burned."

Unless there is no relation between religious beliefs and conduct, science must have a very direct bearing upon conduct also if only through its effect upon religious beliefs. It is true that science knows no closed book, that its content and meaning are constantly changing, but so is our conduct. The

moral of to-day was the immoral of yesterday. Science deduces nothing from absolute principles, and as Berthelot said, "What is deduced from absolute principles is an illusion. Whatever pretends to be supported on the absolute, is supported on nothing"—unless, perchance, man could fathom the absolute.

Since science speaks a universal language, and since the fruits of science can be universally used, it should carry its lessons and influence everywhere and also serve as a common bond among mankind. Goethe wittily suggested that what unites us is the common and not the distinguished. Only a world religion could be a universal bond, and for that our greatest religious leaders see no hope. Men are, of necessity, much more likely to think alike in science. Religions have often been the cause of disunion in the past, and unfortunately even to-day still separate rather than unite, nations or groups of peoples within the same nation. There are many kinds of religion, but only one universal science.

Like Prometheus bound, science has cried out long and loud in protest against many social ills and a mass of avoidable evil and woe that beset us. Many of us have had deaf ears because of a lack of comprehension of ourselves, of our fellows and of the conditions under which we live. In the last analysis I can not doubt that a wiser humanity will mean a kindlier humanity. Ignorance and brutishness go hand in hand. We shall no longer put little children to "hurtful labor" when we have a fuller knowledge of what that means to them, to us and to posterity, and when we shall recognize frankly that children are the result of our own acts rather than accidents or a gift of the gods, we shall feel responsible for the use we make of our procreative powers in wedlock as well as out of it.

In the words of Carrere, "For thousands and thousands of years poor humanity has dragged itself over the earth in pursuit of a happiness that ever recedes before it like a mirage; for long ages men, races and empires have clashed, urged on by a destiny of which none of us yet knows the secret; from the dawn of time we have held up to heaven hands that implore unceasingly and begin ever anew; during the whole of time we have struggled and stumbled through the bloody darkness," but who would deny that but for science this darkness would be "bloodier" still? I am not as confident about the future influence of science as Renan, but when a happier day shall dawn, I doubt not that science will have had very much to do with lighting the way, even if it has not been an open sesame to it. Science alone probably can not save us, but it is very unlikely that theology alone can do so, even after being freed from dross. It is more than likely that man shall need all the resources at his command in order to round out his little day on earth in freedom, peace and happiness. Science may free us from all the dead weight of traditional theology, but if we will "strip ourselves of all that we owe to science" then we may undoubtedly, as Voltaire said to Rousseau, "again live on all fours." Indeed, many of our fellow-men, both primitive and civilized, seem to prefer this unscientific attitude in our own time, but as for me, I prefer to say with Carrere, "I have been in their huts, have smelt their dung heaps. No thank you."

THE ELEMENTS AND SAFEGUARDS OF SCIENTIFIC THINKING

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THE teacher of science has an unexcelled opportunity to develop in pupils skill in that type of thinking called scientific. As Dewey points out, science is quite as much a method as it is subject matter. The teacher who fails to drill pupils in the scientific method is not doing his whole duty as a teacher of science.

We are forced to think only when facing a problematic or, as Dewey aptly calls it, "a forked road," situation. It behooves the science teacher then to throw much of his pupils' work into problem form: just how much will depend on the relative importance he assigns to skill in scientific thinking, to scientific knowledge and to appreciation.

ELEMENTS OF SCIENTIFIC THINKING AND THEIR SAFEGUARDS

The teacher who endeavors to direct pupils in acquiring skill in scientific thinking must have a clear-cut notion of the elements that constitute such thinking; he must be on the alert to detect and correct the errors that pupils are most likely to make in the process. The elements of scientific thinking are essentially the same as for any reflective thinking. It is by the increasing awareness of the safeguards that must be thrown around the successive steps in the thought process that science has made its thinking constantly more cautious.

The following outline will present these elements and safeguards:

Elements of scientific thinking	*Safeguards*
Purposeful observation	a. must be accurate; b. must be extensive; c. must be done under a variety of conditions.
Analysis—Synthesis	d. The essential elements in a problematic situation must be picked out. e. Dissimilarities as well as similarities must be regarded. Danger of analogy. f. Exceptions are to be given special attention. Selective interpretation.
Selective recall	g. A wide range of experience is necessary.
Hypotheses	h. All possible ones must be considered. (Fertility of suggestion.)
Verification by inference and experiment	i. Inferences must be tested experimentally. j. Only one variable is permitted.
Reasoning by: 1. method of agreement 2. method of difference 3. method of residues 4. method of concomitant variation 5. joint method of agreement and difference	k. Data must be cogently arranged. l. Judgment must be passed on the adequacy of the data. m. Judgment must be passed on the pertinency of data.

Elements of scientific thinking	*Safeguards*
Judgment	n. must be unprejudiced;
	o. must be impersonal;
	p. must be suspended if data are inadequate.

RECOGNITION AND DEFINITION OF A PROBLEM

It is evident that two things must precede the solution of any problem, namely, the recognition of the problem and its definition. It is only when the student is facing a clearly-defined problem that his observation will be purposeful.

The initial task of a physician is frequently simply the job of defining a problem. A man comes to his office to consult him who only knows he is losing his customary vigor. He has no particular pain, sleeps and eats fairly well, but just does not feel like his old self. He tires rather easily. He has had several colds during the past winter when formerly he rarely caught one. He does not know what ails him, or that anything really ails him; yet he does not feel fully energetic. So the physician proceeds to give him a thorough examination. He takes his pulse and temperature and finds both apparently normal. He uses his stethoscope to listen to respiration and heart beat. There are no signs of trouble. He takes his blood-pressure, makes a blood count, analyzes the excretions. He finds nothing suspicious. He X-rays his teeth and so discovers bad pus sacs on the roots of some dead molars. The indefinite problem of the patient's malaise now becomes a perfectly definite one of how to best rid him of some badly-infected teeth. The patient knew he was facing a problematic situation. The doctor has clearly defined the problem.

A man who is conducting a previously successful manufacturing business begins to be aware that something is wrong. His monthly trial balances show decreasing profits. He runs on for some time hoping things will take a turn for the better, but no improvement comes. Unable to locate his trouble, he perhaps calls in an efficiency expert. All he can tell the expert is that something is wrong—just what it is he can not say. So the expert looks into the sources of raw materials, their initial cost and the cost of delivery at the plant. He goes over the factory and examines all the items that enter into the cost of production. He looks into the location of the markets where the product is sold, the cost of shipment, the expense of the sales force. Possibly he finds production costs are excessively high and on analyzing the various items discovers that the daily output of certain essential machines per man employed on them is low as compared with other similar factories with which he is familiar. The machines are old and inefficient. The indefinite problem, merely that something ails the business, now becomes the very definite one of the replacement of these antiquated machines with modern models.

Aloisio Galvani (1737–1798), a physician and professor at Bologna, was preparing frogs' legs for his wife. She was ill with some stomach trouble and this delicacy had been prescribed for her. He had skinned a number of the frogs' legs and had laid them on the table when he was called out of the room. A student of his was experimenting with a frictional electric machine on the same table. His wife happened to touch a scalpel to the nerve of a frog's leg when a spark jumped from the electric machine to the scalpel and the leg twitched violently. She related this to Galvani. He recognized in this a problem, not merely a curious fact. He tried to get additional facts. He hung frogs' legs on iron wires on an iron trellis in his garden while a thunder storm was in progress. The legs

twitched violently. He laid frogs' legs on metal plates indoors and touched the nerve with one end of a wire, the other end of which was in contact with the metal plate. Again he observed the twitching of the legs. When, however, he laid the legs on a glass plate and used a glass rod to connect the plate and the nerve, there was no twitching. In these experiments he was trying to define his problem which finally shaped itself into the question whence came the electricity in these frogs' legs? He later decided, erroneously, that it was generated in the nerves. In spite of a wrong solution he had seen and defined a problem.

One wonders in looking back over the history of discovery that men were so slow in making discoveries that now seem readily apparent. Of course "hindsight" is notoriously easier than "foresight." Yet much of the difficulty has come from failure to see that there was a problem and failure to define it clearly. When even physicians believed that disease was a dispensation of Providence, there was possible no problem concerning a cure. Suffering and death were the inevitable lot of man and unquestioningly accepted as such. When "sore throat" included such diverse things as scarlet fever, diphtheria and measles, the problem of a cure could not be undertaken, for the problem was not clearly defined. Typhoid and typhus fevers were confused for a long time and could not be successfully treated or a cure discovered because the problems involved were not clearly defined. The recognition that a problem exists and a clear definition of it are absolutely essential steps. It is immensely important to develop in pupils the problem-seeking, problem-defining attitude of mind.

Historic Instances of Scientific Thinking

The history of science is replete with many instances of the interplay of these elements in the solution of problems. Convex lenses were known from very early times. The Greeks certainly used them as burning glasses. When lenses were used as spectacles and in the microscope and telescope in the early seventeenth century, the problem of exactly how they affect the light passing through them was forced upon the attention of the early scientists. Many experiments were performed, using lenses of varying curvature, both convex and concave, passing a beam of light into glass so it struck the surface at various angles and noting the amount of bending or refraction. So a body of fact was accumulated by purposeful observation. Such experiences were analyzed to pick out relevant essentials. Reasoning on the basis of these led to the tentative hypothesis that there is a relation between the angle of incidence and that of refraction, such that the greater the former, the greater the amount of refraction. This *principle* was confirmed by additional experiments; so the judgment stood as a bit of new knowledge.

But could this relationship be expressed more exactly? Kepler continued the experiments and from a study of his data surmised that when the light passed from air into glass, the angle of refraction was half again as great as the angle of incidence. Repeated experiments confirmed this *law,* if the angle of incidence, that is the angle between the entering beam of light and a line perpendicular to the surface at its point of entrance, did not exceed 30°. Still later Snell and Descartes discovered, by more careful experiments and more exact thinking, the present statement of the law that the sine of the angle of incidence bears a constant relation to the sine of the angle of refraction, which relation is always the same for any given medium; and again this statement of the law of refraction was at first tentatively held merely as a hypothesis, but was confirmed by re-

peated experiment. The law was now definite and exact.

Then, in 1690, Huygen's "Traité de la Lumière" was published in which he explained this, together with other laws and phenomena of light, on the basis of his wave theory. At first, this theory received scant consideration, for Newton's corpuscular theory had general credence, but as it was seen how well the theory explained refraction, dispersion, polarization and other light phenomena, it was generally adopted. Thus has scientific knowledge advanced from principles, expressive of relationships, to laws, in which the relationships were expressed with mathematical precision, to theories that give a basis for the understanding of many laws.

The labors of the alchemists had resulted in the discovery of a good many chemical substances and of methods for their preparation. Such knowledge was, however, a by-product of the main purposes of the alchemists. By the sixteenth century, such chemical substances and processes were becoming of sufficient value in medicine, industry and the arts to make the knowledge concerning them worthwhile for itself. Robert Boyle rejected the old Aristotelian notion of the four elements, earth, air, fire and water, and substituted the concept that an element is a substance that can not be further subdivided and that these elements unite to form compounds. It was not long before chemists began to wonder if there was any definite and fixed way in which these elements unite. They began to sense a problem and one with many practical bearings. For instance, in the reduction of iron ore, should the ore, the limestone and the charcoal be put into the furnace in definite proportions? If so, what were the proportions? To solve problems of this type, chemists began gradually to accumulate facts. Bergman found that one hundred parts by weight of silver precipitates out one hundred thirty-five parts by weight of mercury, from a neutral solution of the latter substance. Cavendish found that there was some sort of a definite relationship in the interaction of acids and bases. Richter showed that it always takes a definite amount of a given base to neutralize a definite amount of a given acid. This principle that chemical action goes on in perfectly definite ways was crystallized into the law of definite proportions of Proust and the law of multiple proportions of Dalton. At first, of course, these laws were proposed as hypotheses. It was only as they were substantiated by the numerous facts brought out by experiment that they advanced to the standing of proven laws. Then Dalton took a long step forward when he explained these laws on the basis of his atomic theory.

Long before the time of Gregor Mendel, facts concerning heredity had rendered clear to mankind the principle that there is a definite relationship between the characters of parents and of their offspring, but Mendel appreciated the need of discovering some exact statement of this relationship, a real law. He recognized that only when such a law was available could breeders proceed with any certainty to produce better plants and animals. It was this problem of the practical breeder that he perceived and clearly defined. So by extensive, purposeful experiments in crossing garden peas, he proceeded to collect facts. These he studied to find, if possible, some significant relationships. He analyzed the complex data, picked out the essentials and synthesized a new idea. He thought he found that one of a pair of antagonistic characters (like tallness and shortness of the vines) dominated in the children. And in the grandchildren there was a definite ratio of three individuals manifesting the dominant character to each one that showed the recessive. This tentative hypothesis was tested by addi-

tional crosses involving other characters. Tens of thousands of offspring were reared. The added facts confirmed the conclusion he had first reached. So he felt that the facts warranted the statement of his law as a well-reasoned judgment. Much later, by similar process of scientific thinking, came the theory of the gene to account for Mendel's law and its extension to the phenomena of linkage, factorial inheritance, etc.

Types of Reasoning in Science

As has been repeatedly pointed out, there are at least five types of reasoning in the inductive thought process; (a) the method of similarities, (b) of differences, (c) of similarities and differences, (d) of concomitant variation, (e) of residues. (Mill's "canons"—See his Logic Book III.)

(a) If, in a changing group of possible causes, one is constant and one effect is constant in a changing group of effects, that cause is the essential antecedent of the effect. Thus Koch found that no matter how variable in other particulars tuberculous patients might be, the tubercle bacilli were always present in their organs, and no matter how variable their later behavior might be, death from tuberculosis was the constant sequence. He therefore concluded that the tubercle bacillus was the cause of the disease.

(b) If, in a group of possible causes, one is always absent, and one effect in the group of effects is also always absent, the absent effect is the consequence of the absent cause. So Koch reasoned that since, when the tubercle bacillus was absent in an animal or a human, death with the characteristic symptoms of tuberculosis never ensued, the tubercle bacillus was the cause of the symptoms and the consequent death.

(c) Combination of these two lines of argument constitutes the method of similarities and differences. The combined method is evidently not always possible.

(d) In the method of concomitant variation, it is assumed that if one possible cause in a changing group is varied and one effect varies concomitantly, the two are related as cause and effect. Boyle found that increase in the pressure to which a given volume of gas was subjected was accompanied by a corresponding decrease in the volume of that gas and *vice versa*, that every decrease in pressure was accompanied by a corresponding increase in the gas volume. He, therefore, concluded that the change in the volume of the gas is caused by the change in the pressure to which it is subjected.

(e) If all the effects in a given group can be accounted for by causes known to be present, except one, and that one effect is accompanied by one cause, that cause is productive of the effect. Thus the irregularities of the movements of Uranus could not be all accounted for by the known attractions of the other heavenly bodies. It was necessary, therefore, to hypothecate the presence of an unknown planet to account for these irregularities. From these, its mass and position were calculated and the planet, Neptune, was discovered, located by reasoning on the method of residues.

Safeguards of the Elements in Scientific Thinking

(a) *Ideas of Accuracy*

It is very desirable to inculcate pupils with ideals of scientific accuracy. In the history of science there are many instances in which even the masters have failed because of their lack of accuracy or have succeeded because of their insistence upon it. When Kepler undertook to determine the form of the orbits of the planets, he based his work on the observations of Tycho Brahe who, for many years, had recorded the positions of the planets. It was because these observations were accurate and extensive that Kepler determined the orbits to be

ellipses and later discovered the laws of planetary movements.

De Saussure thought he saw the microscopic animalcules reproduce by fission and so reported the fact. But Ellis, an Englishman, denied this, claiming that the young came out of the body of the parent. He said he was able to see the children inside the parent and even the grandchildren inside the children. Spallanzani put a drop of broth swarming with infusoria on a glass slide; near it he put a drop of pure water. He connected the two drops by a tiny bridge by drawing the broth out with a fine brush until it connected with the drop of water. Under the lens he watched this bridge until he saw one animalcule swim over into the drop of water. He then wiped the bridge away and sucked the drop of water with its one animalcule up into a fine glass tube. He watched this one animal continuously, saw it divide and the two offspring redivide. This he did again and again until he was sure that de Saussure was right.

When Pasteur went down to Alais to study the silkworm disease that was destroying the silkworm industry of Southern France, he found that the silkworm moths and their eggs and even the worms had in them hordes of tiny globules. This was merely the confirmation of a discovery that had been made earlier by another student of the disease. Pasteur told the farmers to examine the fat under the skin of father and mother moths after the eggs were laid, and if none of these little globules were found in the fat, the eggs would be healthy and would hatch out into worms that would also be healthy. The farmers followed Pasteur's directions, but a great many of the worms still died of the disease. Pasteur had thought that if the moths were infected, the fat bodies would show the globules. His later and more accurate observations proved that it was necessary to examine the fluids from several parts of the moth's body, for the little living organism that caused the disease might be found in certain parts and not in others. It was inaccuracy that led to his early failure in directing the farmers how to combat the disease.

So in modern times we find Professor Michelson spending years in a series of experiments to determine the velocity of light, refining his experiments year after year so as to make the determination with exceeding accuracy. Dr. Paul R. Heyl, working at the United States Bureau of Standards, has just finished an accurate determination of the gravitational constant. Newton's Law states that the attraction of gravity increases with the mass of the attracting bodies and decreases as the distance between them becomes greater. If the figures representing the masses be multiplied together, the product divided by the distance and the quotient multiplied by the gravitational constant, an expression of the gravitational pull between the two bodies is obtained. Since it is important that this be determined with exactitude in mechanics, both terrestrial and celestial, this gravitational constant is an important factor. An Englishman, Nevil Maskelyne, tried to determine it in the eighteenth century by suspending a metal ball of known mass beside a mountain whose mass could be estimated. The metal ball is drawn out of plumb by the attraction of the mountain and by measuring the amount of this deflection, the gravitational constant was determined. The method was not an accurate one, however. The latter part of the same century, Henry Cavendish, also an Englishman, devised a more refined method. A light but rigid bar was fixed at its midpoint on top of one end of a vertical wire, the base of which was also firmly fixed. Small balls of equal mass were fixed to the end of the horizontal rod. Near these balls were

placed large metal spheres of known mass. The mutual attraction of the large spheres and the small ones tends to twist the vertical wire. A tiny mirror was fixed at the top of the wire so that a beam of light was reflected from it to the wall of the room. A very slight twist in the wire made a large displacement of the spot of light on the wall. It is this method that Dr. Heyl has also used with every precaution to measure the deflection with great exactitude. The figure obtained is now 6.664. Much of the rapid advance of science in the modern period is due to the invention of precision instruments that make accuracy possible, like the thermometer, galvanometer and spectroscope.

(b) *Observation must be Extensive*

Observations must also be extensive. The student must be aware of the danger of drawing conclusions from a single instance, or from a few instances. The term oxygen means "acid former" and for a long while it was thought that the combination of certain substances with oxygen produced acids and that acids were only so produced. Later, however, acids were discovered that contained no oxygen. The whole idea of the nature of the acid was, therefore, wrong in the time of Lavoisier, due to the fact that judgments were based on a limited number of cases.

William Smith was an English surveyor whose profession necessitated his traveling all over England. He was also interested in fossils and collected these in many localities and took careful notes on the character and relationships of the strata in which they occurred. It was these extensive observations that enabled him to see that strata with like fossils were formed contemporaneously and that the fossils in the strata could be used as guides in determining relative age of the deposits.

(c) *Observation under Varying Conditions*

Observations need to be made under a variety of conditions. Newton desired, if possible, to make a telescope free from chromatic aberration; that is, one in which the image would not be surrounded by a halo of color. He knew that light passing through a lens is broken up into its component colors just as it is in passing through a prism. He thought it might be possible by a combination of lenses to overcome this defect. To test the possibility of this, he put a glass prism in a prismatic vessel filled with a sugar of lead solution. The apex of the glass prism pointed in the opposite direction from the apex of the prismatic vessel. His idea was that one prism might undo the dispersive effect of the other. He found, however, that the light after passing through both prisms still showed color bands and concluded that the achromatic lens was impossible. If he had varied the condition, however, using a variety of solutions, he would have discovered that some solutions would correct the dispersive effect of the glass prism much more than others and might, then, have hoped to find one that would correct the trouble entirely. Due to this failure of his to vary the conditions under which he worked and due to the great weight of his authority, the discovery of the method of making the achromatic telescope lens was delayed for more than a century.

(d) *Picking out Essential Elements*

In facing a problematic situation it is necessary to analyze the elements involved and to pick out those that are essential in its solution. It is pathetic to see how the old medical men in the days before the discovery of the germ nature of disease were groping around in the dark trying to find the essential

elements in the problem of the cause of disease. It was thought that malaria was due to inhaling the damp night air of swampy regions. Typhoid fever was supposed to be due to decomposition of organic matter; thus the outbreak in New York late in the eighteenth century was thought to have been caused by a boatload of water-soaked coffee brought from Brazil and dumped on the wharf to rot. Wolf[1] relates that in a certain hospital in Dublin many deaths occurred among the patients located on the first floor of the hospital, while few died in the second floor ward. It was concluded that for some unknown reason the first floor was very unhealthful. One essential element in the situation had been overlooked, however. The hospital porter was in the habit of sending all patients upstairs who could walk up, while those who were too sick to climb the stairs were put in the ward on the first floor.

(e) *Importance of Dissimilarities*

The student of science must be aware of the danger of basing conclusions on similarities alone. Quite frequently it is the differences that are manifest that give a clue to the solution of the problem. Basing conclusions on similarities alone has led to many errors and is the basis of the well-known danger of reasoning by analogy. Familiar examples are the common notions that the whale is a fish, that a bat is a bird.

Sir Patrick Manson, usually regarded as the "father of tropical medicine," was in charge of a hospital in Formosa. While on leave of absence, he read of Lewis' discovery of the *filaria* worm in the blood of man. When, in 1875, he returned to China, he instructed two of his native helpers how to examine the blood of native patients for these worms. One of these, who was on duty by night, reported finding many worms, while the one on duty by day reported very few. It was this striking difference that made Manson think that the agency that transmits the worm from person to person was probably active by night and since the worm inhabits the blood, it was probably some bloodsucker. This made him suspicious of the mosquito. Examination of the mosquitoes found in the hospital wards confirmed his suspicion. It was the carrier of the filaria worms that caused elephantiasis.

Yet reasoning by analogy is safe if adequate experimental check is made on the conclusions. Franklin was struck by the similarities in the electrical discharge from a Leyden jar and lightning. Both gave light; both ran a crooked course; both made a crackling noise, destroyed life, were accompanied by a sulphurous smell. But he tested his hypothesis that they were the same by his famous kite experiment.

(f) *Exceptions Always Significant*

Exceptions to the general rule always need careful consideration. The old adage that the exception proves the rule uses the term "prove" in the sense of test. The exception tests the rule, and frequently strains it to the breaking point. When Bateson crossed two white-flowered sweet peas and obtained purple-flowered offspring, he discovered an exception to Mendel's Law that necessitated the modification of that law, well-known now as the factorial hypothesis. That same law was again under necessity of modification when the exceptional behavior of sex-linked characters was considered. The student of science must learn not to ignore exceptions, but to pay special attention to them.

(g) *Wide Range of Experience*

The value of a wide range of experience as a basis for selective recall is constantly evident in the history of

[1] Wolf, A., "The Essentials of Scientific Method." Macmillan.

science. Joseph Lister was a surgeon in the Edinburgh Infirmary when gangrene was rampant and septic poisoning killed a high percentage of the patients. In Munich it was estimated that eight out of ten people operated on died of gangrene. Lister knew that gangrene was a putrefaction of the flesh. The very odor in the hospitals was evidence of that. But what was the cause of the putrefaction? When a paper of Pasteur's fell into his hands, showing that putrefaction was caused by micro-organisms, Lister saw at once that gangrene was something that attacked the patient from outside and that it was not "in the blood" as was formerly supposed. He recalled that in the city of Carlisle the sewage was freed of its vile odor by mixing it with carbolic acid; presumably then the carbolic acid destroyed the germs of putrefaction which was going on in the sewage. It was this ability to cull out of his broad experience this incident, apparently entirely unrelated to hospital practice, which suggested that wounds be treated with carbolic acid. The suggestion led to his system of antiseptic surgery that reduced the death rate in hospitals amazingly, until it was a mere vestige of its former high figure.

A bit of experience, while out sailing, enabled James Bradley, professor at Oxford in the seventeenth century, to solve a perplexing problem in astronomy. Many of the stars seemed to shift their position about twenty seconds of arc every year. He could not see why. While sailing he noticed that the weather vane on the mast shifted its position each time the boat changed its course. He thought, at first, that the wind must be veering, but the boatman said the direction of the wind was constant, but the vane took a direction due to both wind and the direction of motion of the boat. Then Bradley saw that the apparent position of a star would be determined by the direction in which the light from the star was traveling and the direction and rate of motion of the earth in its orbit about the sun. At one part of the year the earth would be moving in the opposite direction from the direction it traveled six months earlier. Hence the apparent displacement.

(h) *Consider All Possible Hypotheses*

There is an excellent illustration of the necessity of considering all possible hypotheses in Spallanzani's experiments on spontaneous generation. Needham found that many tiny organisms appeared in mutton broth, even when the latter had been boiled and then kept in tightly-corked flasks. The same thing, he said, happened in a soup made of seeds like peas. Spallanzani, however, sealed the necks of his flasks in a flame, thinking that possibly the corks could not be set tightly enough to prevent micro-organisms in the dust of the air getting in. After the flasks were sealed he kept them and their contained soup in boiling water for an hour. When, days afterwards, these were opened and the soup examined, no living things were found. But Needham said that when soup was thus boiled for so long a time the "vegetative force" which it contained was destroyed. So Spallanzani boiled some of his soup for an hour, some for two hours, and put it into flasks whose necks were merely corked. He examined the contents of the flasks a few days later and found more of the micro-organisms in the soup that had been boiled two hours than in that which had been boiled only one. He also baked beans and peas until they were charred almost black, so as to destroy any "vegetative force" that they might contain, but soup made from these and allowed to stand yielded the living organisms, just as well as that from the fresh seeds. Again, however, Needham objected that the elasticity of

the air was destroyed in Spallanzani's flasks and that the organisms could not exist without normal elasticity. Spallanzani drew out the necks of the flasks in a hot flame without sealing them. He then put these flasks into boiling water and left them for an hour or more. Then when they had cooled, he sealed the tiny opening at the tip. When these flasks were opened in due course of time, no living organisms were found in the broth, although the air pressure in the flask was greater than that outside, for when the tip of the flask was broken, a flame placed near the opening was blown away by the escaping air. One hypothesis after another had to be considered and each disproven before Spallanzani felt convinced that there was no such thing as spontaneous generation. One who is familiar with the history of this idea knows that after the time of Spallanzani, other hypotheses had also to be considered and disproven.

(i) *Test the Inferences from Hypotheses*

Hypotheses must be verified experimentally always, if possible. A chance experience of Oersted's (1819) showed him that a current of electricity passing through a wire held parallel to and over a compass needle causes the needle to be deflected. Argo found that a wire through which a current is passing attracts iron filings. Possibly it is to be considered a magnet. Two such wires, then, Ampère thought, should attract each other like magnets. He confirmed his inference by experiment. Then Michael Faraday said that if the current in the wire makes the magnetic needle move, a moving magnet should produce a current in a nearby wire. This inference he tested and found true.

Heat was, by the earlier physicists, thought to be a material substance, caloric, that was taken on when a body became hot and given off when it cooled. Rumford inferred then that a body should gain in weight when heated. He weighed a cannon that was to be bored and the boring tool. They were weighed again when the boring was done. Both cannon and tool were made very hot by the boring, but neither had gained in weight. In this case the caloric hypothesis was not verified and Rumford concluded it was untenable.

(j) *Allow Only One Variable*

It is exceedingly important that in all experiments to test the inferences from an hypothesis or for that matter in any experiments, all factors be kept constant except the one variable whose effect is being tested. Some of Pasteur's opponents, unconvinced that the bacteria were the cause of anthrax, drew blood from a sheep that had died of the disease and injected some of this into rabbits. These rabbits died promptly, although no anthrax bacteria were to be found in their bodies, showing, to their way of thinking, that the bacteria had nothing to do with the death of the sheep. But they had waited so long before introducing the sheep's blood into the rabbit's that putrefactive changes had developed poisons that killed the rabbits before the anthrax germs had a chance to multiply. A whole set of new variables had arisen that vitiated the results of their experiments.

Falk in his "Principles of Vital Statistics" quotes an experience of Dr. Vaughan that shows to what ridiculous conclusions one may be led by using data involving a number of variables. "In 1888, at an international medical congress, I ventured to offer a paper in which I suggested that summer diarrheas of infancy might be due to poisonous milk. When the paper was opened for discussion a learned, elderly man arose, and after making some feeble, complimentary remarks directed to the writer, proceeded to demolish all his claims, and finally he suggested that the

high infantile mortality, which was becoming greater and greater every year, could be attributed to the more common use of the baby perambulator because, he said, and no one could deny the statement, that the death-rate among children in this country had increased since the baby cab had come into use. When I arose to close the discussion, I said that I would withdraw all that I had claimed concerning poisonous milk, that the argument adduced by my critic could not be contradicted, but I would suggest that the high infantile mortality was due to the fact that we were more in the habit of carrying umbrellas than our ancestors, or that possibly it might be due to the fact that we eat more tomatoes than our grandfathers did."

(k) *Skill in arranging Data*

To arrange data and the arguments based upon them in such cogent form that the conclusions are most readily discerned is one of the eminently desirable skills to be achieved through scientific studies. Numerous recent studies have shown that both in individual laboratory work and in demonstrations from the instructor's desk, students are woefully inept in drawing conclusions from the data presented. They know reasonably well how the experiment was set up and what happened in it, but the meaning of it is obscure. They have not been forced to state the evidence so cogently that its significance is apparent. The experiments in science classes may easily degenerate into mere "busy work" unless the teacher holds pupils rigidly to the necessary reasoning that makes the experiment meaningful and transforms experiences into real science.

To quote samples would occupy space unnecessarily. To cite them is sufficient. Read, for instance, Lyell's "Principles of Geology" to see how cogently he states his facts and his arguments to show that geological processes have not been primarily catastrophic, but are ever operating slowly but surely, the same yesterday, to-day, and forever, to produce geological changes. So he transformed the old Wernerian geology into the modern science. Or, again, read Agassiz's "Studies on Glaciers" to see how he marshals his facts and his arguments to prove the part played by these agencies in transforming the physiographic features of the temperate continental areas. Read Darwin's epoch-making "Origin of the Species" and you will appreciate another fine example of the patient but masterly mustering of an array of data in orderly and potent form for the successful attack on a difficult problem. The masters of science have been masterful because they were experts in this art of the cogent arrangement of facts and arguments. The beginner needs much drill in this same art. It is one of the rare opportunities of science instruction.

(l, m) *Pertinency and Adequacy of Data*

The student of science must constantly be trained to pass critical judgment on the pertinency and adequacy of the data he is using. Robert Boyle (1627–1691) realized in a measure at least how essential it is to judge the pertinency of the data bearing on a problem. He severely criticizes the old alchemists for their impertinency. He writes in "The Sceptical Chymist": "If judicious men, skilled in chymical affairs, shall agree to write clearly and plainly of them, and thereby keep men from being stunned, as it were, or imposed upon by dark and empty words, 'tis to be hoped that these men (the Alchemists) finding that they can no longer write impertinently and absurdly, without being laughed at for doing so, will be reduced either to write nothing, or books that may teach us something, and not rob men, as formerly, of invaluable time; and so ceas-

ing to trouble the world with riddles or impertinencies, we shall either by their books receive an advantage, or by their silence escape an inconvenience.'' Many of the alchemists posed as magicians, and alchemy was allied in the popular mind with the black art. The naive beliefs of these pseudo-scientists warranted Boyle's criticism. How uncritical they were of either the pertinency or the adequacy of the data on which such beliefs rested is apparent from the following typical remedy of these magicians. When a goat sneezes violently some of the worms are expelled from its brains into its nostrils. These are to be carefully extracted, placed in a cloth without allowing them to touch the ground, then three of them are to be tied in the thin skin of a black sheep and worn around the patient's neck. This is a sure cure for epilepsy.

A sapphire was supposed to nourish the body. The wearer could neither be harmed by fraud, nor envy, nor could he be moved by terror. It would free a prisoner who wore it. It helped in attaining answers to prayer. It healed ulcers, stopped headache, cured diseases of the eyes and reduced fever.

One realizes how essential it is to be ever critical of the adequacy of the data on which conclusions are based, when he sees the many, many errors into which the older scientists were perpetually falling because the data at their command were insufficient. The old Ptolemaic cosmography held sway for many centuries with the earth as the center of the universe and the numerous epicycles thrown in to the orbits of the planets to explain apparent irregularities in their movements. This was in spite of the fact that Pythagoras and his followers had earlier proposed the modern system. The crucial data were not forthcoming until the days of Galileo and Tycho Brahe to make the Ptolemaic system untenable. The pathway of scientific advance is so littered with the wrecks of discarded ideas and discredited theories that it behooves the science teacher to cultivate in pupils a critical attitude on the adequacy of the data he is examining. There is no greater danger than a too ready scientific credulity. The students who may pick the flaws in our present day scientific notions are in training in our schools to-day. They need to be alert to the inadequacy of the data on which we are basing some erroneous conclusions. Only a blind optimist could hope there were none such.

(n) *The Unprejudiced Attitude*

The judgments passed by the scientist must be unprejudiced, that is, he must free himself from preconceived notions and reach his conclusions on the basis of the evidence in hand. For a century before Priestley's day, burning had been explained as the process of giving off a principle called phlogiston. If a substance would not burn, it was said to be already ''dephlogisticated.'' Priestley discovered oxygen. He prepared it by heating the red oxide of mercury, then called red calx of mercury, and collecting the gas over a pneumatic trough. The new gas would not burn, so he called it ''dephlogisticated'' air. He showed that this ''air'' was necessary to combustion and to respiration. He visited Lavoisier in France and showed him his method of making the gas. Over a century before Jean Ray had shown that the calx of a metal is heavier than the metal, and Lavoisier showed that when a metal burns (or oxidizes) to form the calx, the latter is heavier than the metal by an amount equivalent to the weight lost by the air. He further showed that the air also loses in the process the power to support combustion. Lavoisier concluded rightly that the burning is a union of the burned substance with oxygen as he called

Priestley's "dephlogisticated air." But Priestley was so saturated with the phlogiston notion that he could not free himself from it, his judgment was prejudiced, and he remained to the end of his days a "phlogistonist."

(o) *Impersonal Judgment*

Judgment must be objective, impersonal. The scientist must free himself from personal bias and base his conclusions on the evidence in hand in spite of personal preferences. Humphry Davy, experimenting on a rabbit, and then on himself, discovered that nitrous oxide or laughing gas produced momentary insensibility when inhaled. Michael Faraday, later, found that sulphuric ether would accomplish the same result. In 1844, Dr. Horace Wells, of Hartford, Connecticut, painlessly pulled a tooth with the patient under the influence of nitrous oxide. In 1846, Dr. Marcy, of Boston, removed a tumor while the patient was under ether. In 1847, Dr. J. Y. Simpson used ether and chloroform to relieve suffering in childbirth and persisted in spite of tremendous opposition, based on the biblical curse pronounced on Eve. One would think that so great a scientist as Dr. Simpson with his background of experience would be open-minded on a scientific problem. Yet he opposed Lister's method of antiseptic surgery, biased against Lister apparently because Lister had devised a method of tying blood vessels, in operations, with gut, which replaced Simpson's method of closing the vessels with needle-like instruments. Simpson could not free himself from personal animosities and judge solely on objective evidence.

(p) *Suspended Judgment*

Finally the scientist must hold his judgment in suspense until the evidence is overwhelming. In a letter to Asa Gray, under date of July 20th, 1856, Charles Darwin wrote: "Nineteen years ago it occurred to me that whilst otherwise employed on natural history, I might perhaps do good, if I noted any sorts of facts bearing on the question of the origin of species, and this I have since been doing. Either species have been independently created or they have descended from other species, like varieties from species. I think it can be shown to be probable that man gets his most distinct varieties by preserving such as arise best worth keeping, and destroying the others. . . . I assume that species arise like our domestic varieties. . . . I believe I see my way pretty clearly on the means used by nature to change her species and adapt them to the wondrous and exquisitely beautiful contingencies to which every living being is exposed." This theory of the origin of species was not published until 1859, three years later. For nineteen years judgment had been suspended while evidence accumulated. Now in 1856 he sees his way pretty clearly; such caution is truly scientific.

ANIMAL HUSBANDRY AND WAR

By SYDNEY HILLYARD

In the breeding of animals the work of one man is not enough to furnish more than a mere foundation upon which his sons, grandsons and great-grandsons must build. The work of selection—the picking out of the strongest or fastest horse, the heaviest wooled sheep, the cow with the most or the richest milk—must continue for generations unbroken, or we can quickly have a retrogression, a devolution back to the wild stock—a much easier thing to get than an evolution toward the perfect specimen that has become so necessary to modern life.

Thousands of English sheep farmers, unknown and unsung, from Edward the Sixth to Edward the Seventh, a matter of three hundred and fifty years, have patiently and persistently picked out their best rams or bought better ones, and have raised the net value of the sheep of their country by a slightly thicker wool or a shade heavier mutton. This is all there is to breeding, but it takes two things—time and security. An army turned loose in a sheep country for a winter will eat the sheep or drive them off and the farmer has to begin a century's breeding all over again with runts, where his great-grandfather left off. And this is the case whether it is your own army that is encamped, fighting or maneuvering over your country or your enemy's. This was very well shown in the Hundred Years War between England and France and in the Thirty Years War that was fought all over Germany.

The English archers who fought with the longbow at Crecy, Agincourt and Poitiers did not care how many or what kind of sheep were left in France after the army was fed. The hide of an extra-fine fleeced ewe would make a pillow, a patch or a washrag. The mutton of an oversize tup filled the more mess cans. The soldiers of Gustavus Adolphus or of Wallenstein, whether Protestant or Catholic, ate about the same amount, and being in Germany, they ate German sheep. At the end of thirty years there were so few cattle and sheep left in Germany that the starving peasantry were eating human flesh. It takes a century to get a breed of animals well started; it takes a week to wipe it out. On the continent of Europe this has happened again and again, until one wonders how anything larger than a performing flea with a lusty jump is left alive.

And this brings us to the following question: Why have nearly all the great breeds of domestic animals that are now scattered all over the earth, the horses, cattle, sheep, hogs, been originated and perfected in England? Why not elsewhere? If it takes three centuries of careful breeding, watching and protection to raise a perfect horse that a war can wipe out in three hours, why have so many breeds been perfected in England and so few elsewhere? Let us see how England stands in this matter of animal breeds, and then let us ask how this has come about, and what it has to do with war and disarmament. First, let us see if there be one country which stands out above all others in the initiation and consummation of bred stock and then let us deduce a theory to fit the demonstrated facts.

Let us take horses. The great Shire, Clyde and Suffolk heavy horses are the most widespread draft horses of the world. They haul the beer-wagons of

Berlin, the water-wagons of New York and the plows of Alberta, Queensland and the Argentine. The Shire, with his shaggy legs, the Clyde with his round belly, the Suffolk with his thick neck, each took many lifetimes of farmers to bring him from runthood to drafthood, from a rangy scarecrow to a mastodon of one ton. So with the English thoroughbred, the fastest of living animals. It is literally running circles all round the globe. You can lose a dollar on him as easily at Saratoga as at Sydney or Epsom Flats.

The word "Shire" in connection with horses was first used in the statutes of Henry VIII, in 1530. Under various names—the War Horse, the Great Horse, the Old English Black Horse, the Shire Horse—this breed has for centuries been cultivated in the rich fen lands of Lincolnshire and Cambridgeshire. He is the largest of horses. The thoroughbred comes later, beginning probably with "Markham's Arabian" in 1616. Three other horses followed, Byerly Turk, Darley Arabian and Godolphin Barb, and from these animals all the race horses of to-day have descended. From Henry the Eighth, he of the many wives, and Charles the Second, when America was getting nicely started, to this day, these, the largest and the fastest horses, have been patiently nursed.

The American standard trotter dates from the Darley Arabian through the Hackney and Norfolk trotters. Its career is similar to that of the thoroughbred and for the same reasons.

As with the horse so it is with the cow; both with the big beef breeds and the little dairy breeds. The red-faced Durham ox and the white-faced Hereford, the Devon, the Angus and many other beef steers are British stock, while the milkers, the Jersey and Guernsey, are from the Channel Islands.

The Brown Swiss and the Simmenthaler are continental cows and have come to maturity apparently for the same reason as have the world-wide English breeds. They have been raised in the Swiss mountains, exposed to storms and snow but sheltered from soldiers.

The first scientific breeder of cattle was Robert Bakewell, of Loughborough, Leicester, England. This man made thousands of pounds out of his bred stock. The Collings brothers followed him and started the Durham cattle with "Hubback" in 1777. The Durham is the same thing as the Shorthorn, now the most widely spread of all cattle. One Tompkins followed Collings with the Hereford, and then a Mr. Watson with the Angus, and a John Ellman, who founded the Southdown. These people did not invent the cow; they inventoried her, started her on the narrow path and made a doomsday book in which to record her. And she has nobly responded. The Chicago stockyards demonstrate this.

"What shall we debate?" was the question in the good old days back on the farm at the first literary and debating society's meeting in November.

"Which is more useful, the horse or the cow," came the invariable answer. In the ranch country the horse won the decision; in the farm settlements, the cow. But whichsoever way the embattled farmers voted, it remained proved that a team consisting of a horse and a cow had helped haul civilization for a long distance.

An Englishman and an Irishman may differ as to some things, but they see with one eye when it comes to a hog, and the American is there with them. In fact America really leads the field. But it is enough for our story that the Berkshire, the Yorkshire, Tamworths and other breeds were British, with the American Durocs and Chesters descended from the same source. There is no continental hog worth spearing. Without England and America the hog

would be a razorback in the forest, useless to himself or to any one else.

England has done wonders in chickens with the Brahmas, the Plymouth Rocks, Orpingtons and others too numerous and too noisy to mention, but here again the American hen has it. The Yankee rooster has a right to crow over all comers for size and over all scrappers except the English fighting cocks. Outside of the Anglo-American hen there is not very much to write home about. The campfire kettle is hard on the poultry yard; always has been—and always will be.

The goat has had the best chance of them all at self-development. He started first. All the wandering sheiks from Abraham down had goats, but it is probable that the simple-minded nannie in your vacant lot is little better than those that Isaac milked. The Angora goat is the product of the mountains of Asia Minor and the Caucasus and of other secluded mountain districts, as the brown Saanen and the white Toggenbung of Switzerland. England and the United States have never tackled goat-breeding. The goat has had to live in fastnesses where he could jump down a precipice when a foraging party showed up. Had he found favor with a breeding nation what might he not have been?

But it is in sheep that the tight little island has simply done it all. It has been "Let George do it," and in truth it is perhaps in the reigns of the four Georges more than at any time in eight hundred years that English sheep rose to supremacy.

There are a dozen major breeds of sheep from the English and Scottish counties which cover the hills of Christendom and the valleys of heathendom. Such are the Cheviots, the Oxfords, the Southdowns, the Shropshires, and others. There were no other sheep until Vermont, Australia and New Zealand developed the modern Merino.

All the mutton sheep are English.

Now we can carry the argument a step further. We find that war destroys domestic animals; we find that the principal animal breeds were produced in England. Why has England been able to do it?

Because of the English Channel.

That strip of water but twenty miles wide has done it. It is narrow, to be sure, but enough to keep the restless armies of continental Europe off the island since 1066. It was enough to keep England free from invasion for eight hundred years, while armies, including English armies, were tramping over Europe, eating and destroying the cattle, sheep and goats and using up the horses in their cavalry. Poland, Germany, Austria, Italy and France have had enough wars to knock out each and every attempt at animal breeding as fast as it was made. It is a wonder they have any animals at all.

Almost every European government has at one time or another tried to get animal breeding going except that of England. The English government alone seems to take no interest in it, and there alone has it been a complete success. The English farmer was left in peace by the armies, with a couple of civil wars for exceptions, to improve his sheep generation after generation, century after century, with the result described. Had a successful invasion of England say, by Spain in Elizabeth's time, or by France in Anne's time, or by Germany in Victoria's time, swept all over the country where would the thoroughbred horses be? Where would the Cotswold sheep be? Where, the Durham cattle? Thus went the continental animals—to carry the cavalry into battle and to feed the infantry after it.

"The Kaiser had the finest of the old English estates already parceled out among his favorites before the war started," said an Englishman to the

writer. "One of his sons was to have the seat of the Dukes of Portland." Just how true this is may be a question, but another question is, how many prize cattle would be left on the estates of England by the time Hindenburg and Ludendorff had got themselves into secure possession of them?

"There will be precious few Englishmen left alive to see it," said a British officer when the talk veered to what Germany would do with Britain in the event of occupation. If there would be precious few Englishmen left how many English thoroughbreds would there be? Answer: None.

During the Spanish invasion of the Low Countries the Dutch cattle were raised only in Schleswig. The Spanish armies destroyed them elsewhere. In 1786 the Germans imported some merino sheep that the French government had introduced from Spain and had established on a government farm near Paris. Something prevented the continuous development of these sheep, the kind of development that has taken place in America and Australia, and that something is in part war. In the latter part of the seventeenth century the French government began the systematic development of stallions in the vicinity of Paris in the province of Normandy. The French have met with success in the Percheron horse, a draft animal much favored in America. A professor of agriculture informed the writer that he attributed survival of this horse to the fact that it was bred in that part of France, La Perche, which has been most free from invading hosts of all the country. The snow-white Emden goose and the Holstein-Friesian cattle originated in the lowlands adjacent to the North Sea. East, west, and south of them are rivers and turf bogs. No armies, the writer is informed, have ever maneuvered across that territory.

The Belgians have a fine draft horse, but we are informed that this last war has left the United States in possession of all the best of the breed. Similarly, the Russian government in 1777 started a stud of the Orloff horse. It is said that few of the finest of these horses will have survived the last six years of war. It would be nothing less than a miracle if they could, and animals aren't saved by miracles—at least not in wartime.

It is true that the opposite side of the case can be argued at least as regards the horse. The French Coach Horse, the German Coach, and other continental saddle and driving horses are the result of various governments having selected and bred horses for cavalry. Yet this can apply to the breeding situation in only a limited way; it is true only of horses and to some extent of mules and applies only to a certain kind of horse. Once the army is supplied, the government's interest stops. All credit is due to the continental coach horse as a product of war, but it must not be forgotten that these very coach horses are used to kill each other on the battlefields, and to kill off other animals, so that the better the war horses the better foraging the cavalry can do and the more lambs and chickens they can gather in for the evening soup kettle.

Governments that breed men and animals for war are primarily interested in war. If there is anything that the World War has shown it is that the governments of Europe would sacrifice everything to win the war. The three kaisers now unhorsed would and did allow the war to go on until the resources of their peoples were exhausted—that is to say that the Prussian kaiser was willing to allow his own people to be destroyed rather than resign and lose his own crown and honor. The raising of horses by such people is not an asset in animal breeding; it is a liability. Governments that will stand by and see their race destroyed rather than their own personal

pride and power, are not animal breeders; the only creatures in their stock registry are the four horses of the Apocalypse.

The United States will be the nursery for the great breeds of the future. One hundred and twenty-five thousand dollars has been paid in this country for a single bull—the world's record for dairy animals. The American wool sheep, the American hog, the American milch cow now lead the world, and we are rapidly coming up in other breeds. There is no knowing what can be done if no armies devastate the farms and no poison gas murders our animals. But let us have peace. We have heard the call of the wild, the call of the carpenter, the call of the cities, and several other calls, now let us hear the call of the cow.

In "The Next War" Will Irwin has shown what the effect of airship, gas and poison may be on humanity. What will their effect be on the priceless breeding stocks? Will not humanity, for its immediate preservation, be compelled to sacrifice, to consume, whatever of its best animals the armies and artillery have left behind, if they leave any? Has this not already taken place in Poland and Russia and Serbia?

America is to-day the capital of the financial world. It is also becoming the capital of the animal-breeding world. If peace, on one little island, has brought forth these splendid breeds of animals that have served the world for centuries, what may it not achieve on this great continent if no recurring animal slaughters prevent? The horse, the cow, the hog and the sheep all call for disarmament.

Let us have peace.

JOHN LINING, AN EARLY AMERICAN SCIENTIST

By FRANKLIN C. BING

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ALMOST two hundred years ago there emigrated to this country a Scotch youth of twenty-two, named John Lining. He settled in Charleston, then called Charles-Town, in the Colony of South Carolina, and there practised medicine for thirty years until his death in 1760. Although he was an outstanding figure in the history of early American science there remains but one very brief biographical account of him, that by David Ramsay.[1] He was educated in Scotland and held the degree of Doctor of Medicine, probably, according to Dr. Wilson,[2] from the University of Edinburgh. Details of Dr. Lining's entire life that remain to us are very scanty. He had a fairly large practice, it is said, and enjoyed considerable renown for his scientific attainments. He is always referred to as "the celebrated Dr. Lining" or "the ingenious Dr. Lining" by contemporary writers. To him we owe the earliest experiments on metabolism made in this country. The first description of the symptoms of yellow fever that came from America was in a letter written by him to the professor of medicine at the University of Edinburgh. He even experimented with electrical phenomena and communicated with his famous colonial contemporary, Benjamin Franklin, upon this subject. Lining seems to have corresponded extensively and it is from those letters published in the Transactions of the Royal Society of London and in a publication of a Medical Society of Edinburgh that we obtain our knowledge of the work of this active and versatile investigator.

His experiments upon metabolism were the result of an effort to ascertain the relationship, if any, between weather conditions and epidemic diseases. This was the time of sweeping epidemics such as practically are unheard of to-day. Two years before his arrival in Charles-Town the inhabitants of that city had been afflicted by an epidemic of yellow fever. This malady occurred again in 1732, and it was then that Lining obtained his first experience with this disease. It was observed that yellow fever, like some other diseases, occurred only in the summer and lasted only until cold weather set in. Building upon this fact, Lining began making and recording systematic observations on the weather, starting in 1738 and continuing for several years. During the year of 1740 he made in addition measurements of his own metabolism, these measurements being made in a regular fashion every day for an entire year.[3] The object of this extended experiment is best stated in Lining's own words, as given in the preliminary report, made after observations extending over several months:

"What first induced me," he says, "to enter upon this Course, was, that I might experimentally discover the Influences of our different Seasons upon the Human Body; by which I might arrive at some more certain Knowledge of the Causes of our epidemic Diseases, which as regularly return at their stated Seasons, as a good Clock strikes Twelve when the Sun is in the

[1] Ramsay, David. "The history of South Carolina." Vol. 2 (1808).

[2] Personal communication from Dr. Robert Wilson, of Charleston, S. C., to whom I am indebted for first interesting me in the history of early American science.

[3] Lining, J. Metabolism Experiments. *Trans. Roy. Soc.* *42*, 49 (1743). Ibid. *43*, 318, (1745).

Meridian; and therefore must proceed from some general Cause operating uniformly in the returning different Seasons."

To study the weather conditions from day to day Lining had a complete set of meteorological instruments. A whipcord hygroscope was used for recording the relative humidity of the air. Lining recorded the appearance of the sky, whether it were clear or cloudy, and the amount of cloudiness. He made an instrument, which he did not describe, for ascertaining the amount of rainfall. He recorded also the force of the wind each day, remarking that this factor played an important part in cooling the body by evaporation of the perspiration. For this measurement he had no instrument, but judged by the senses. He used Fahrenheit's thermometer to record temperatures, and in addition, a peculiar type of thermometer made by a Thomas Heath, of London, which was divided into ninety equal parts, 65 being freezing, and 49 temperate. The modern Centigrade thermometer was, of course, unknown in those early days. The difficulties of experimental work scarcely can be appreciated, when even the commonest instruments of the modern laboratory were either not yet developed, or had to be improvised by the experimenter himself. A contemporary of Dr. Lining calibrated his own thermometer by measuring off the inches between the lower fixed point, the temperature of melting ice, and the upper, the temperature under the armpit of "a man in health."

For studying the effects of the environmental conditions upon the human body, Lining made careful measurements upon himself. Each day he would record his weight upon arising, and also before retiring at night. At these same times he would ascertain and record his pulse rate. All the food that he ate during the course of the day was weighed, and all the liquids that he drank were measured. Each day he would record the amount of his urine, the weight of his solid excreta, and the quantity of perspiration given off. The latter figure was obtained by carefully weighing his dry clothes before wearing them, and also after taking them off. The increase in weight of the clothes was recorded as the amount of perspiration. During the summer months these weighings had to be made several times in a day.

"Thus," says he, "have I now spent near One Year, with no small Labour, Confinement, and Expence in the Loss of Practice, in making these Experiments and Calculations; and if they will be of any Service to Mankind . . . shall then obtain all I had in View, in entering upon the Course."

His second paper concluded the data for the year and tabulated it. It is interesting to observe that he contemplated performing blood tests upon himself, but was forced to refrain from so doing because of the crudeness of the available methods of that day. He states:

That I may be furnished with as many Data as possible, I propose to take the specific gravity of the Cruor, of the Serum, and Crassamentum of the Blood, in different Diseases, and in their several Stadia, by a very nice hydrostatic Balance, made by Mr. Jackson. But this indeed is attended with greater Difficulties than I was at first apprised of, for the Experiment requires a greater Quantity of Blood than can at all times be safely taken away; and Rain-water, with which the specific Gravity of the Blood is compared, I have found, by repeated Experiments, to lose about 3/512 Parts of a Grain for each Degree of Heat by Fahrenheit's Thermometer; and Oil of Turpentine, in which the Crassamentum is weighed, loses much more of its specific Gravity.

Present day readers may well remark at the painstaking nicety of Lining's experimental technique, considering the date at which it was done. The spirit of his experimental procedure throughout is thoroughly modern.

The data accumulated by Lining showed conclusively that the volume of the urine is roughly inversely proportional to the amount of perspiration; the amount of perspiration being greatest in the hot months of summer and

least in the winter, and the volume of the kidney secretion being, conversely, greatest in winter and least in summer. Dr. Lining was content to give his data and his protocols. Other men made use of his information, and sometimes constructed fantastic theories to account for his results. Thus, we find that Dr. George Milligen[4] divided acute fevers into those of the hot months and those of the winter months, and gave a very involved and hypothetical explanation of their production as a result of weather conditions.

Patrick Ker,[5] a medical student at the University of Edinburgh, in 1746 attempted to correlate the occurrence of several diseases with the weather conditions in Edinburgh and in nearby towns, but his work was mainly statistical rather than experimental. The spirit of Lining's work, on the other hand, might well serve as a model for students pursuing similar investigations to-day. He formulated his hypotheses clearly and tested them out fully and carefully, making use of the best available instruments of his day. He checked his methods carefully, and was not loath to criticize any defects of his own experimental technique. That all this was done by a man working alone and unaided in a country miles away from the great intellectual centers of the world is all the more remarkable. Two recent investigators[6] in the field of "insensible perspiration," writing of the history of the determination of the amount of perspiration, have expressed amazement at the patient thoroughness of Dr. Lining's experimental work. For years these observations of this little known American investigator remained the most complete and extensive on record.

Dr. Lining extended his meteorological observations over several years and these accounts of Charles-Town weather were published in the Transactions of the Royal Society.[7] Dr. Lionel Chalmers[8] continued these observations later, from 1750 to 1759, and when the Medical Society of South Carolina was formed such observations were made as a matter of routine, beginning in 1791.

Dr. Lining also is the author of the first accurate account of yellow fever that reached European centers from this continent.[9] It is in the form of a letter addressed to Doctor Robert Whytt, Professor of Medicine in the University of Edinburgh. It is essentially a history of the yellow fever as it appeared in Charles-Town in 1748. "In this history," says the author, "I have confined myself to a faithful narration of facts, and have avoided any physical inquiry into the causes of the several symptoms of this disease . . . " Dr. John B. Beck,[10] as late as 1842, stated that this account "stands to this day unrivalled for the general accuracy and minuteness of its description." Doctor Lining, however, believed that the disease was imported and contagious, and it is interesting to note that for many years afterwards the laws of South Carolina guarded against it as such.

About this time the attention of many men was directed towards electrical phenomena. Benjamin Franklin had

4 Milligen, George. "A short Description of the Province of South Carolina." London. (1770).

5 Ker, Patrick. Weather and Epidemic Diseases. In Lewis, Condensed Volume of Medical Essays and Observations, published by a Society in Edinburgh. Page 77. London (1746).

6 Benedict, F. G., and H. F. Root. Insensible Perspiration. *Arch. Int. Med. 38*, 1 (1926).

7 Lining, J. Meteorological Data. No. 487, *Trans. Roy. Soc.* Ibid. *48*, I, 285 (1754).

8 Chalmers, Lionel. "An Account of the Weather and Diseases of South Carolina." London (1776).

9 Lining, J. "Essay on Yellow Fever." Supplement to Chisolm, Colin: "An Essay on the Malignant Pestilential Fever." Philadelphia (1799). Originally published in Edinburgh. Essays and Obs. *2*, 370 (1753).

10 Beck, John B. Annual Presidential Address delivered before the Medical Society of New York. February 1, 1842.

already published his famous Treatise on Electricity, and in 1752 he wrote an account of his famous kite experiment.[11] Lining is said to have communicated with Franklin, and is known to have repeated some of his electrical experiments. An account of several kite experiments made by him is given in a letter sent in answer to queries made by a Charles Pinckney, of London.[12] Mr. Pinckney wished to know more about Dr. Lining's experiments, and particularly whether any danger was attendant upon performing them. A Professor Richman in Petersburg had been struck by lightning and killed while performing electrical experiments, and Dr. Lining's correspondent wanted to know the reasons for this unfortunate mishap. It seems that Professor Richman had lost his life during the summer of 1753 as he was observing the effects of lightning upon a "gnomon," or kind of device for measuring the magnitude of an electrical charge. Lining astutely inquired in return for more details about the apparatus used by Richman and also asked whether the iron rod by which the lightning was conducted to the instrument had any connection with the earth. It developed that Professor Richman's apparatus was connected directly with a lightning rod at the time when he performed the experiment, and that the lightning rod had no other connection with the ground.

A few years later, in 1760, Dr. Lining died at the early age of fifty-two. In that year an epidemic of small-pox visited Charles-Town and nine hundred and forty persons died of it, whereas but eighty-seven died of all other diseases combined. Whether Dr. Lining succumbed to this malady or not the available records do not state. His fame, however, long survived him. To-day he is worthy of recognition as one of the early scientific investigators of this country, and as a man who, with the same actuating motives of the best scientists of to-day, worked under difficulties that to the ordinary individual would have been well-nigh insurmountable.

11 Franklin, B. Kite Experiment. *Trans. Roy. Soc.* *47*, 565 (1752).

12 Lining, J. Kite Experiment. *Trans. Roy. Soc.* *48*, II, 757 (1754).

A WINTER SLEDGING EXPEDITION ON THE INLAND ICE OF GREENLAND

By HELGE BANGSTED
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Narrative of Journey

In the winter of 1925–1926 I undertook a sledging expedition over the Greenland inland ice from a base at Umanak, a northern colony of the West Coast in latitude seventy degrees north. This journey was undertaken without any special preparation, for it had been my intention to go as far north as Cape York; but I was not permitted to proceed beyond the Umanak district because of an epidemic which had broken out among the children of the northern district, and so my plans had to be changed.

I set out from Umanak near the end of January with two companions, Georg Strang, a moving picture operator, and an Eskimo, Kalepatuk. Our equipment we carried on two sleds, my own with a team of ten dogs, and one of twelve dogs owned by Kalepatuk. At the village of Ikerasak (the narrow sound), 40 kilometers to the south-eastward of Umanak, I was joined by two Eskimos with dogs and sled, and from there, on February 3, we started on our long journey which was the first ever to be made in midwinter over the inland-ice of Greenland.

As already mentioned, I had on leaving Copenhagen in August no intention of making any sledge trip over the inland-ice, and for this reason I had not brought with me the instruments which would have been desirable. I had with me, however, an alcohol compass, some alcohol thermometers for measurement of low temperatures, a small aneroid barometer, and a hodometer or sledmeter constructed from an old bicycle wheel with its attached cyclometer.

From Ikerasak we took our course over the sea-ice to the mainland at Kekertak, about ten kilometers to the westward of the foot of the Great Karajak Glacier, near which had been from 1891 to 1893 the base of the German Greenland Expedition under Professor Erich von Drygalski (see Fig. 1). The sea-ice we found very rough and hummocky, and it took us two days to cover the twenty kilometers between Ikerasak and Kekertak. Fortunately the weather was fine and the air very cold.

At Kekertak we encountered new difficulties in ascending the course of one of those rare rivers for Greenland which persist throughout the winter, and as a consequence by freezing solid to the bottom, they flood the surface and again freeze at the top so as to produce the troublesome "*sersinek* ice" (the ice which grows wider).[1] This surface ice is often so thin that sled, dogs and men all break through and have a bad time with the icy water and the low air temperatures.

After two days of traveling in the *sersinek* ice we left the river and now took our course through the high mountain country up to Isortok. Here the inland-ice comes down as a long smooth tongue up which traveling should not be difficult.

Before leaving Umanak the white residents, and the Greenlanders as well, had all assured me that it was an impossibility to travel on the inland-ice in the winter time. They argued that we should find the surface covered deep

[1] See page 254.

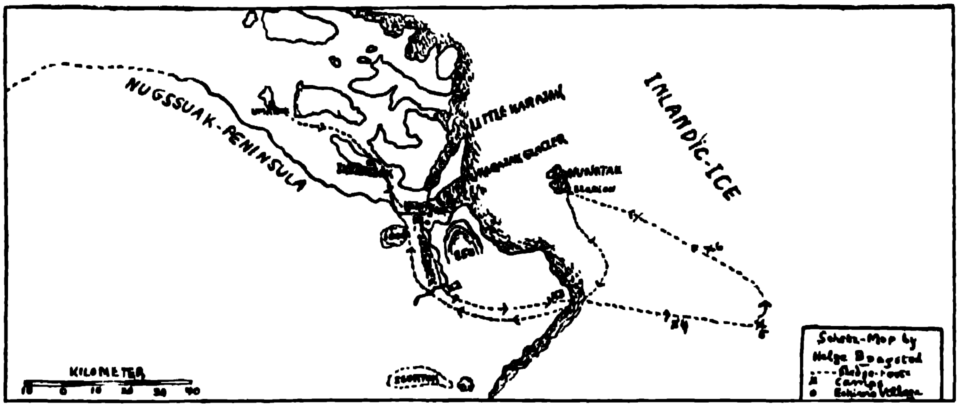


FIG. 1. MAP OF THE VICINITY OF UMANAK TO SHOW THE ROUTE FOLLOWED BY THE EXPEDITION

with soft snow; but this I could not believe, for all explorers of the inland-ice had reported there is always a wind blowing outward from the interior, and wind always compacts the snow and gives it a hard surface. It was therefore difficult to understand how the surface could consist of deep soft snow.

The next morning after reaching Isortok we started off on the inland-ice over the best sledging surface I had ever seen either in Greenland or in Arctic North America when I was connected with Rasmussen's Fifth Thule Expedition of 1921–1923. I had planned to go in to the big nunatak (rocky island within the ice) which lay to the northward and in a general direction to the eastward of Kekertak, but which had as yet never been visited. The Greenlanders had had much to say of the dangerous crevasses which they asserted lay between my present position and this nunatak; and so, instead of steering direct, I shaped my course to the south of east in order to keep clear of them. Not until we were about 80 kilometers in from the ice-margin did I change my course and steer directly for the nunatak itself.

By the middle of February I had reached the nunatak with no difficulties except such as are caused by the cold and stormy weather with drifting snow. Upon the inland-ice close to the nunatak I now set up a rather primitive meteorological station, and here I made observations every hour. This was possible because of the three members composing the party. Throughout eighteen days and nights of drifting stormy weather these observations were kept up (see page 255).

The Sersinek Ice

As has already been explained, we had encountered a very big area of *sersinek* ice along the course of the river which runs out to the Karajak fjord to the southward of the little island of Kekertak. The origin of such ice has a great deal of interest for the scientist, and in Greenland, where rivers usually disappear in the winter-time and are not common even in summer, the *sersinek* ice is very limited in its occurrence. It is restricted, apparently, to the areas of the basalt sheets, particularly Disko Island and the peninsulas of Nugsuak and Svartenhuk, but here it is of common occurrence.

In the autumn when air temperatures are low enough for freezing of the river, a cover of ice forms and by another month the mouth of the river will be frozen solid to the bottom. The water

coming from the springs within the basalt sheets now flows out over the ice-dam near the coast. The pressure of the water may break the ice-dam, but it floods a wide surface, and in calm weather a very thin ice cover will form over the flooded area, and large openings within this cover will permit the water to issue at the surface and again overflow. This process may continue throughout the entire winter.

Observations made on the Inland-ice

On two occasions during our stay of eighteen days near the nunatak[3] we had strong north-east storms, each of which blew for three days in succession. A vast amount of snow was carried out by the wind, and when we went outside the tent we found the drift so thick that we could hardly see the hand when held before the face. When we first reached the nunatak the ice surface had very little snow upon it, but when we left there was a snow cover about six inches deep and this was not soft but hard. The strong blizzard winds had packed the snow together. In the first of these blizzards our tent had been blown to pieces, and it was a very difficult matter to put it again in such a state as would protect us from the snow and the much worse wind.

During these northeast storms we had some days with foehn-wind. At such times the thermometer rose very quickly from—37° C. (-34° F.) to -8° C. (+ 18° F.). Long before the arrival of the foehn we could see the fine foehn clouds off to the southeast. The foehn-wind is a particularly trying wind to encounter on the inland-ice during the winter-time. Very quickly the snow becomes wet, and it collects on the clothing and, what is worse, on the sledge-runners as well.

Throughout our entire stay on the inland-ice I observed that the wind was always blowing outward from the interior of the inland-ice. We had not a single day—not a single hour—when the wind blew inward from the land toward the ice. Another fact is worthy of mention here. On some days we had no wind at all within the depressed areas of the ice-surface, though at the same time it was drifting very badly upon the higher surfaces. I especially noticed this when we were returning to Umanak. Whenever we were on the top of a ridge we encountered the strong northeast wind and drifting snow, but when we had rushed down into a depression of the surface the wind and drift ceased. Only with very strong wind have I observed the wind and drift within the valleys also.

[3] About twenty miles within the ice margin.

The Surfaces of the Inland-ice

As already stated, the inland-ice comes down into the Nugsuak peninsula as a long tongue. On this tongue there was very little snow, not more than two or three inches, and this snow was not, as had been believed, soft but hard. It would be reasonable to suppose that because of the constant drifting outward there would be a large amount of snow, and perhaps also soft snow, at the edge or very close to the edge of the inland-ice. Also because of the heavy drifting near the nunatak it would be easy to believe that the snow would stop and be deposited near the edge of the inland-ice. But this is not so, and the reason is simple enough. The tongues which go out from the inland-ice have a very slight gradient and the surface of the ice is smooth. There is, therefore, nothing to stop the drifting snow until it has reached the big hills on the peninsula. The results are much the same wherever these conditions prevail near the west coast of Greenland, and little ice is deposited at the ice-margin during the winter. Farther south, however, where there is a good deal of hummocky ice, the rough surface will, of course, stop the snow and the valleys between the hummocks will become filled up.

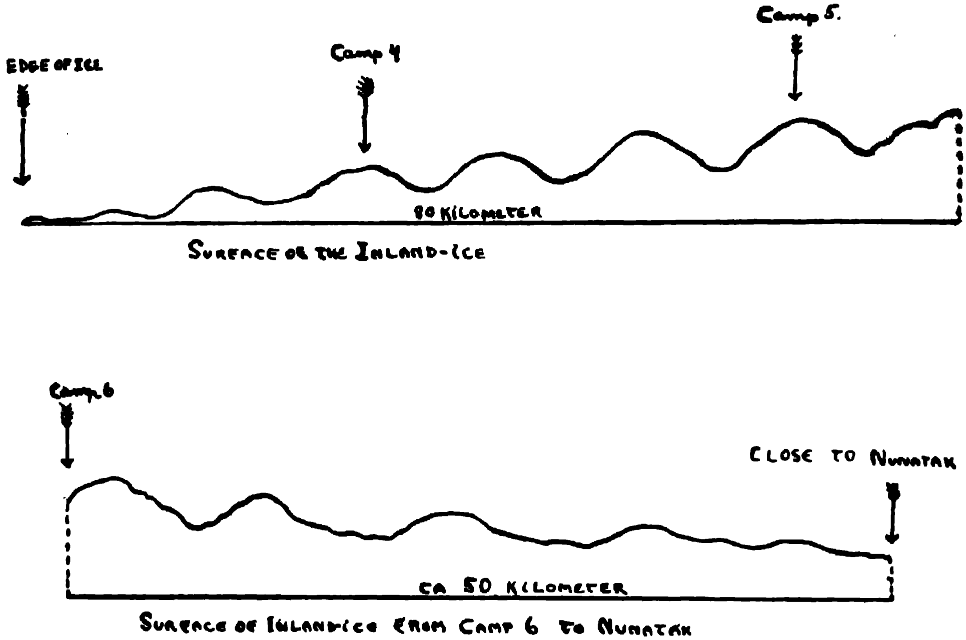


FIG. 2. PROFILE ALONG THE ROUTE OF THE EXPEDITION FROM THE EDGE OF THE INLAND-ICE TO THE STATION CLOSE TO THE NUNATAK

INLAND-ICE SLEDGING IN WINTER

The sledge trip here described was undertaken as a reconnaissance in preparation for expeditions which I have hoped to make later. Heretofore practically all travel over the inland-ice of Greenland has been restricted to the summer season. If a man can manage to live on the inland-ice in the winter, when there is no sunlight or only a few hours of sunlight each day, we are certain to learn much of great interest and value, and from the little trip which I have made I know that it is possible. The chief difficulty[3] is to protect oneself against the frost, and especially against the wet foehn-weather; and then, of course, one must be able to take in sufficient food for oneself and the dogs. On the journey here described we lived mainly on seal meat and on raw frozen halibut—very good as food but also very heavy. There is but one way to manage it if the expedition is to spend a long time on the ice. There must be a sufficient supply of pemmican, the one type of concentrated food which is adapted to ice conditions. Equally important is it to be provided with the very best fur clothing and sleeping-bags that can be obtained.

[3] As a member of the University of Michigan Greenland Expedition of 1927–1928, Mr. Bangsted is now (November, 1927) at the base of this expedition located at the head of the Söndre Strömfjord under the Arctic Circle in southwest Greenland, and with Professor J. E. Church, Jr., will attempt during the coming winter to penetrate by dog-sled the inland-ice for a distance of perhaps one hundred miles where within a cave in the snow they will attempt to set up for as many weeks as is practicable a meteorological station.—The Editor.

CAPTURE OF AN OCEAN SUNFISH

By Dr. E. W. GUDGER
AMERICAN MUSEUM OF NATURAL HISTORY

SOME years ago I published a short note[1] on a thirty-foot whale shark, *Rhineodon typus*, captured by being speared on the bow of the Munson liner *American Legion*. This occurred on May 19, 1923, in Lat. 17° 57′ S. and Long. 38° 41′ W., northeast of the Abrolhos Light, off the southeast coast of Brazil. Recently I have recorded[1] an absolutely similar capture of a fish of the same species and about the same size in the northwestern part of the Gulf of Guinea, near the mouth of the Sassandra River, in Lat. 4° 28′ N. and Long. 6° 24′ W.

The New York daily papers of October 18, 1926, all carried an item from the New York offices of the United States Steamship Lines concerning a somewhat similar capture of a large fish. This was contained in a wireless message from Capt. A. B. Randall, of *The Republic*, reporting a storm as follows: "Easterly gale three days. Only damage caused by an 800-pound live fish, unknown species, washed aboard by heavy seas over forward hatch, carrying away part of rail."

The rotogravure sections of the New York papers of Sunday, November 7, contained pictures of the fish, which at a glance was recognized as *Mola mola*, or, as it is often called, *Orthagoriscus mola*, the ocean sunfish.

A letter to the office of the United States Lines brought four excellent photographs from the Press Aid Department, showing the fish in position as it landed on the rail of *The Republic*. Two of these are herewith reproduced with appreciative thanks to the publicity department of the steamship company.

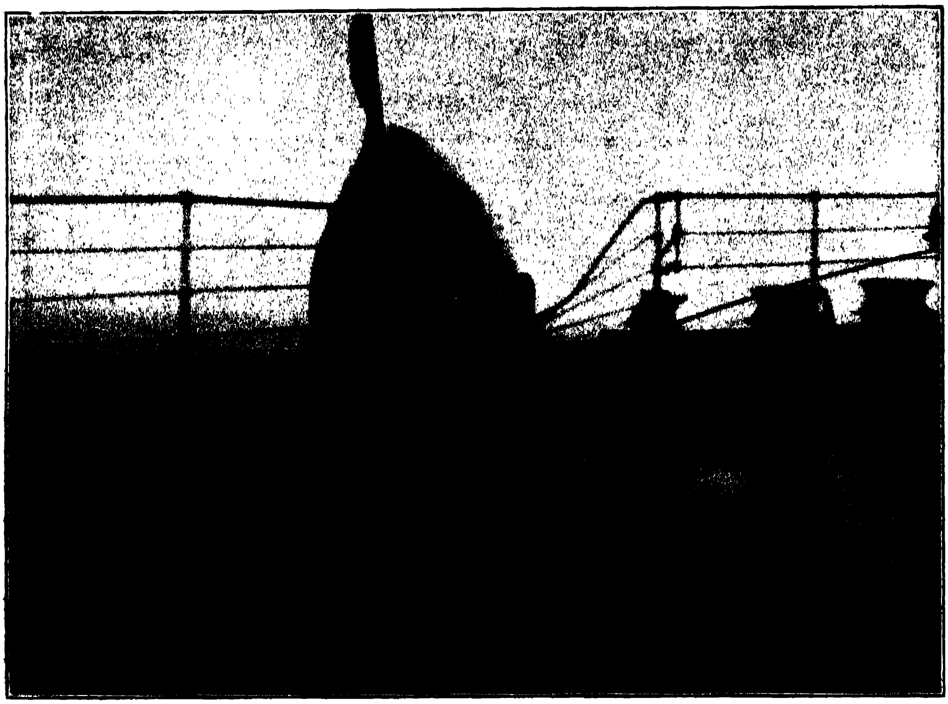
A letter to Captain Randall brought a courteous answer, giving the following details. The fish came aboard on October 17, 1926, when the ship's position was Lat. 49° 58′ N. and Long. 25° 05′ W. —near the center of the north Atlantic. The manner of its boarding the vessel was as follows:

> A moderately easterly gale had been blowing for three days, and the ship was pitching heavily and shipping solid water over the bows. At times the bow of the vessel would go under as much as seven feet, and it was at one of these moments that the fish came aboard.

The extreme ("over all") length of the fish was six feet, its thickness in a right and left direction was twenty-eight inches, its depth just forward of the huge dorsal and anal fins was forty-two inches, and its weight was estimated at 800 pounds. To get the total depth one must add the heights (about twenty inches each) of the two fins named (the dorsal and anal fins) —$42 + 20 + 20 = 82$ inches. The fish then was 6 feet 10 inches deep by 6 feet long. This specimen is to be judged as about two-thirds grown in comparison with fully adult specimens.

The American Museum possesses a mounted specimen measuring 10 feet in length by 11 feet vertical (over dorsal and anal fins). This was taken in 1910 off the coast of Southern California. The mounting of this fish proving unsatisfactory, it has been prepared by the Akeley method and now gives us a very handsome specimen of this interesting fish. At the time of its capture this

[1] Gudger, E. W. "An Extraordinary Capture of the Giant Shark, *Rhineodon typus*." *Natural History*, 1923, Vol. 23, pp. 62–63. "A Second Whale Shark, *Rhineodon typus*, Impaled on the Bow of a Steamship." *Bulletin*, New York Zoological Society, 1927, Vol. 30, pp. 76–77, fig.



A NEARER VIEW OF THE OCEAN SUNFISH
AS IT CAME TO REST ON THE RAIL OF THE STEAMSHIP "REPUBLIC." NOTE THE COLOR MARKINGS.

specimen was the record fish of its kind and was so described by Dr. Bashford Dean.[2] A photograph of the newly mounted fish is herein reproduced as figure 3.

Recently Mr. Zane Grey, the well-known novelist and deep sea angler, has presented a large mounted specimen of the sunfish to the new Hall of Fishes of the museum. This measures 7 feet 6 inches in extreme length and is 10 feet deep. The dorsal and anal fins are each 2 feet 9 inches long, and this leaves the depth of the body proper 4 feet 4 inches. The estimated thickness (right-left diameter) is 4 feet 6 inches. The diameter of the eye is 3 inches.

Other almost equally large specimens are on record. Dr. David Starr Jordan saw one which was taken in 1893 near Los Angeles, California. Its length is given as 8 feet 2 inches "over all," and its weight as 1,800 pounds. In 1915 Dr. B. W. Evermann[3] examined and measured in San Francisco a large specimen captured about 40 miles off the Golden Gate and south of the Farallones. This was 9 feet long and 7 feet 9 inches deep. The dorsal fin, which had been mutilated, was 2 feet 5 inches long and 23 inches wide, and the anal measured 21 inches in length. The eye was 5 inches in diameter. The fishermen estimated its weight at 2,500 pounds, but Evermann's estimate was 1,800 pounds.

Another very large specimen was captured off Santa Catalina Islands in 1919 by Van Campen Heilner. This he fig-

[2] Dean, Bashford. "A Record Sunfish." *American Museum Journal*, 1913, Vol. 13, pp. 370–371.

[3] Evermann, B. W. "Note on an Unusually Large Ocean Sunfish." *Copeia*, 1915, No. 20, pp. 17–18.

THE OCEAN SUNFISH
WHICH CAME ABOARD THE STEAMSHIP "REPUBLIC" IN MID-ATLANTIC. NOTE THE SIZE COMPARED WITH THAT OF THE MEN STANDING NEARBY.

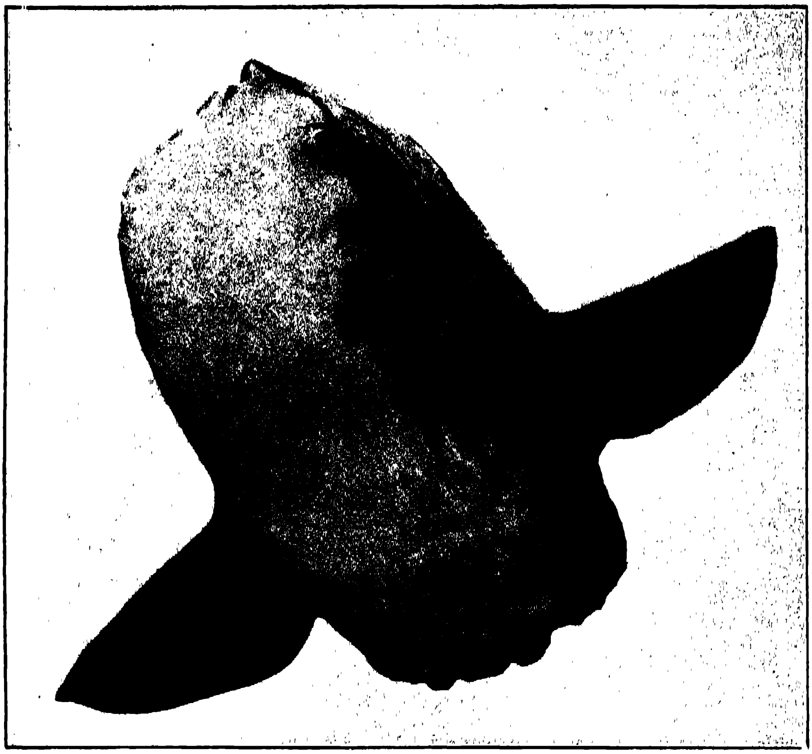
ured and described in 1920.[4] It measured 10 feet 11 inches from tip of snout to tip of tail fin, and 10 feet 9 inches in depth from tip to tip of dorsal and anal fins. This is the most symmetrical fish of which measurements are available.

However, the record sunfish (unfortunately not attested by any scientific man) is figured and described in *The Wide World Magazine* for December 10, 1910, pp. 204–205.[5] The capture of this great fish bears a not remote resemblance to that which forms the subject of this article, since it was taken also by a steamer—but by the propeller. Here follows the account:

When the *Fiona* [a twin screw steamer belonging to the Colonial Refining Company of Sydney, New South Wales] was off Bird Island, about forty miles north of Sydney Heads, on her way from the Clarence River to Sydney, a little after 1 p. m., all hands were alarmed by a sudden shock, as though the steamer had struck a solid substance or wreckage. The result was strange and remarkable, for the port engine was brought up "all standing." The starboard engine was quickly stopped and a boat lowered and sent to investigate. On getting under the steamer's counter the boat's crew were astonished to find that a huge sun-fish had become securely fixed in the bracket of the port propeller. One blade was completely embedded in the creature's flesh, jamming the monster firmly against the stern-post of the vessel. It was impossible to extricate the fish at sea, so the boat was hoisted on board again and the steamer proceeded on her passage to Sydney with the starboard engine only working. On reaching Port Jackson, the *Fiona* was anchored in Mosman Bay, where all hands were set to work to remove

[4] Heilner, Van Campen. "Notes on the taking of an Ocean Sunfish (*Mola mola*) off Santa Catalina Island, California, September 3, 1919." *Bulletin* New York Zoological Society, 1920, Vol. 23, pp. 126–127, fig.

[5] I am indebted to Dr. F. A. Lucas for calling my attention to this interesting note, and for the loan of a copy of the journal.



THE HUGE MOUNTED *ORTHAGORISCUS MOLA*
IN THE HALL OF FISHES, AMERICAN MUSEUM OF NATURAL HISTORY.

the fish. After much difficulty, and with the aid of the steamer's winch, the sun-fish was hoisted clear and swung on board. The *Fiona* then proceeded to the Sugar Company's wharf. The fish was put on the company's weigh-bridge, and found to weigh two tons four hundredweights. The measurements were: Length, ten feet; across the body, six feet; across the body and fins, fourteen feet; mouth, eight inches wide; dorsal fin, four feet high and two feet six inches across; anal fin, three feet six inches; and the caudal or tail fin, twenty-two and a half inches long—a short, fringe-like stump. The flesh near the mouth, where the propeller cut through, was a large mass of whitish cartilaginous substance.

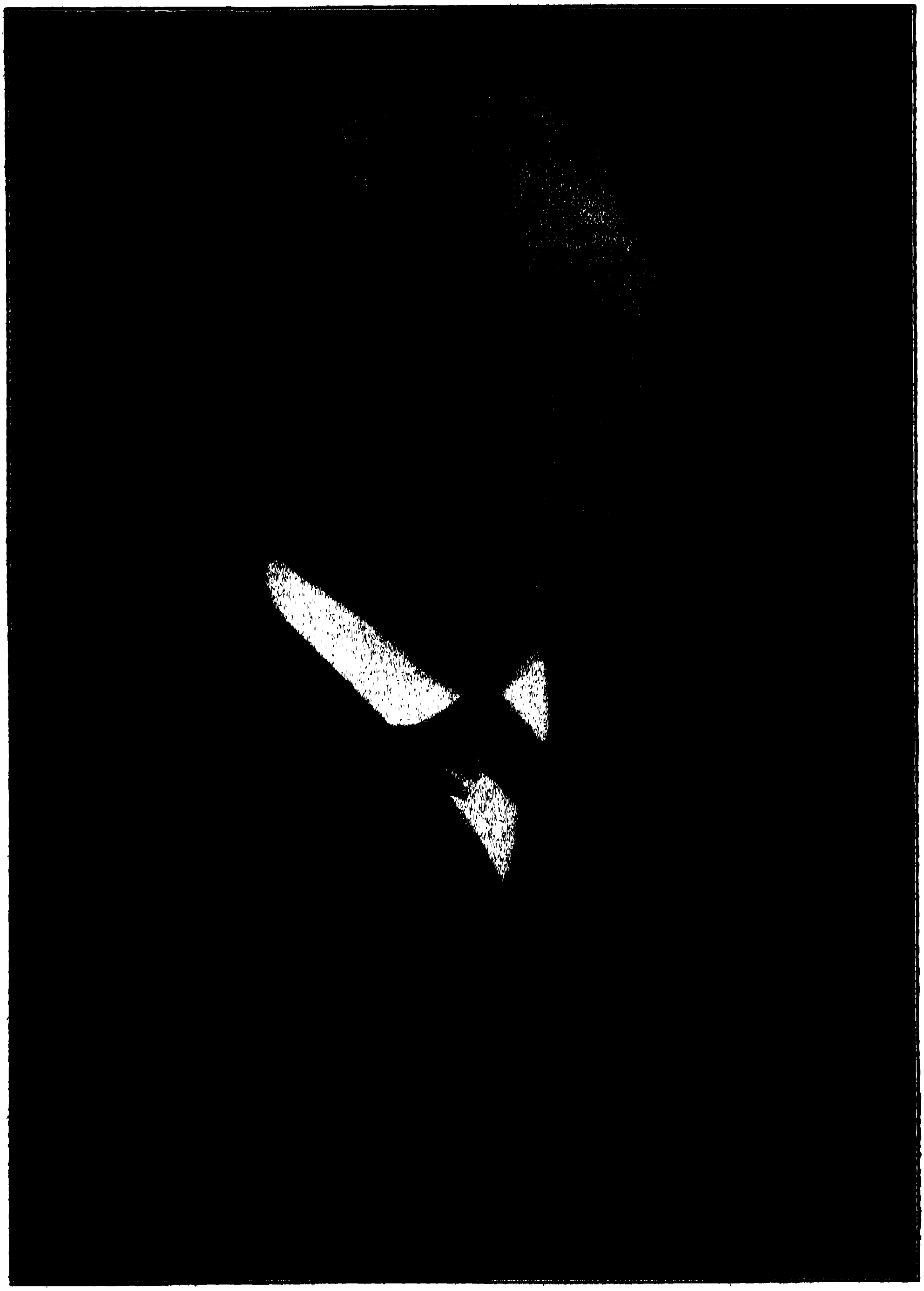
The figure of this fish is herewith reproduced (no. 4 herein), and its size compared to the height of any of the bystanders does not seem to have been exaggerated in the above account. This figure shows three large cuts inflicted on the left side of the head of the fish by the blades of the vessel's propeller—one just in front of the left gill opening, another in the left side of the chin region, and behind these a huge cut in the lower jaw and throat region. Here it was that the propeller blade was imbedded in the thick cartilaginous-like material lying just underneath the skin, and the engine was "brought up all standing."

The capture of both these fish is undoubtedly due to the structure and habits of *Mola*. The short, stumpy, aborted caudal fin is of no service whatever as an agent of locomotion. The thick, heavy, stiff dorsal and anal fins are far from efficient helps in swimming. It does

THE RECORD OCEAN SUNFISH
(LENGTH 10 FT., DEPTH 14 FT., WEIGHT 4,400 LBS.) CAUGHT IN THE PROPELLER OF A STEAMER NEAR SYDNEY, AUSTRALIA.

progress somewhat by slow flappings of these fins, the dorsal projecting above the water generally, but it is most often seen lying on one side at the surface of the water slowly carried along by the waves and currents.

While thus floating at the surface, Captain Randall's fish was picked up and washed aboard as the vessel drove her nose through the waves. In the same way the Australian specimen fouled the vessel's propeller by being drawn close alongside her as she passed the floating fish. Certainly, however, these are two of the most extraordinary captures ever recorded for such a large fish.



EDWARD EMERSON BARNARD[1]

By Professor ROBERT G. AITKEN

LICK OBSERVATORY

NASHVILLE is known as a prosperous commercial city, as the capital of a great state, and as one of the foremost educational centers in the Southern States. Founded as "the advance guard of western civilization" in the days of the war of the revolution, it has had a long and honorable history, with many achievements of which its citizens and all Americans may well be proud. But to the astronomers of my generation all of these claims to recognition are secondary to the fact that Nashville was the birthplace and early home of a man whom we greatly honored and deeply loved—Edward Emerson Barnard.

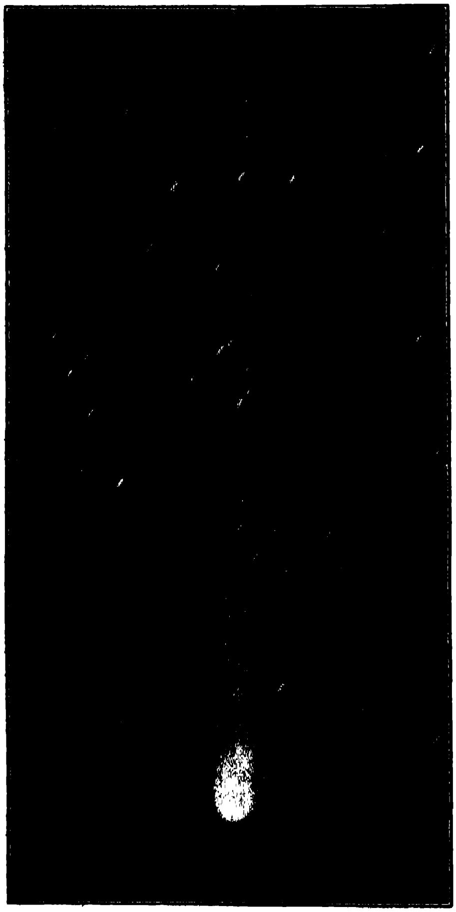
It is my privilege, as retiring chairman of Section D of the American Association for the Advancement of Science, to tell you something of his life and work, that you may know why we so honored and loved him, and to tell you also something of the progress of astronomy in America in those fields in which he was most interested and which his own work helped to make fruitful. It is peculiarly appropriate that special tribute be paid to Barnard's memory on this occasion, for not only was Nashville his birthplace, but it was at the first Nashville meeting, in 1877—fifty years ago—that he became a member of the association.

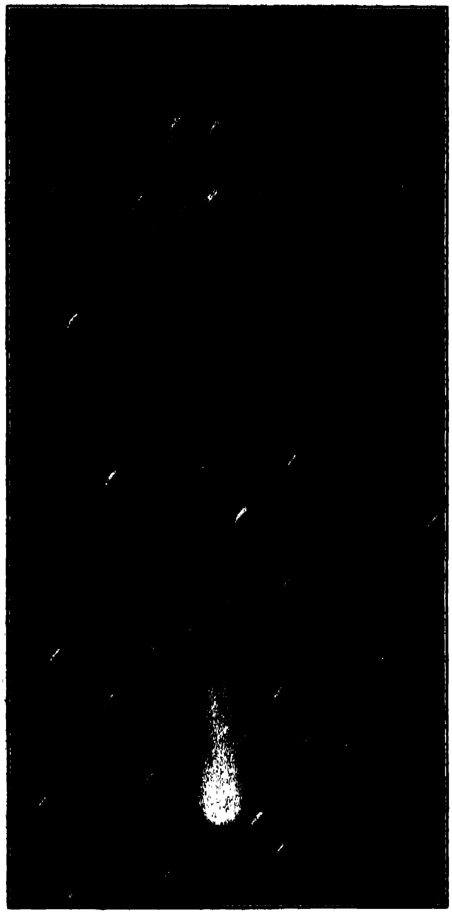
The story of Barnard's early life has been told many times, but it will not be amiss to repeat it, at least in outline, for, according to the behaviorist school of philosophy, what a man is and does in his mature years is conditioned almost exclusively upon the environment of his childhood years. It is not necessary to subscribe to this doctrine and all that it implies to recognize the fact that hard and bitter as were many of his experiences, the circumstances of his early life had a controlling influence in shaping the course of his later career.

Edward Emerson Barnard was born just seventy years ago this month—on December 16, 1857, to be precise. His father, Reuben Barnard, himself a poor man, had died before the boy's birth, and upon his widow, Elizabeth Jane (Haywood) Barnard, fell the heavy burden of providing for herself and her two young sons. The years of the Civil War, and those immediately following, were bitter ones, and a poor family must have suffered many hardships. Children, even very young children, had to help to earn their own support, and it is not surprising to learn that Edward Barnard attended school but two months in his boyhood, and that he went to work at an early age.

But that does not mean that his education was neglected. His mother was a woman of character and of ideals and to her the boy owed not only the rudiments of his education but also inspiration for his struggles throughout his boyhood and youth. Her health failed under the strain of work and care and for some years she had to give up the attempt to have a home of her own. It was only after Barnard's marriage that he had the great satisfaction of having his mother with him again, to be cared for by him, and particularly by his wife, until her death in 1884.

[1] Address of the retiring chairman of Section D, Astronomy, at the Nashville Meeting of the American Association for the Advancement of Science, December 28, 1927.



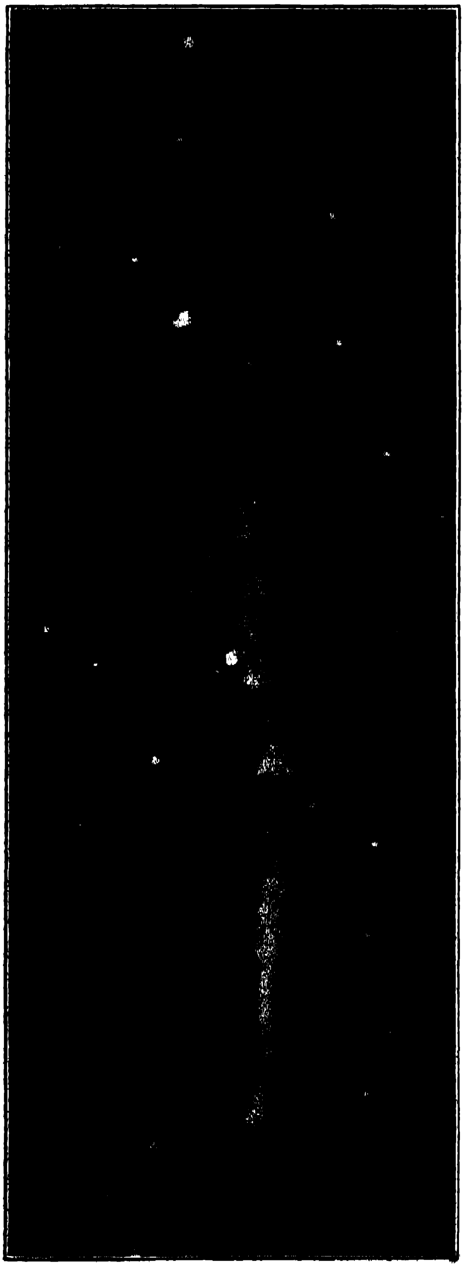


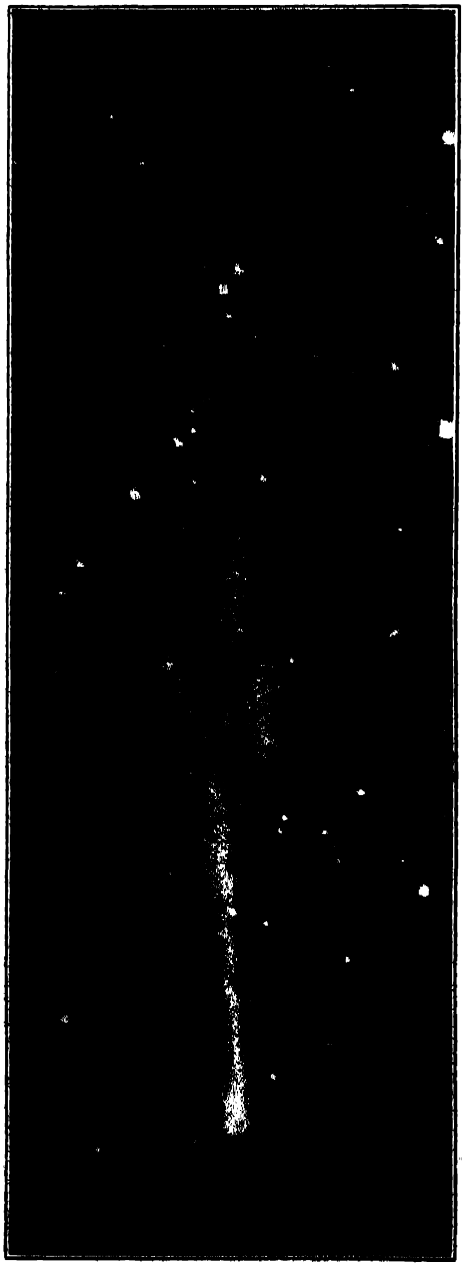
COMET SWIFT

PHOTOGRAPHS TAKEN BY E. E. BARNARD, WITH THE CROCKER TELESCOPE, AT THE LICK OBSERVATORY. THE LEFT-HAND PHOTOGRAPH WAS TAKEN ON APRIL 6, 1892, AND THE RIGHT-HAND PHOTOGRAPH ON APRIL 24, 1892

One circumstance of Barnard's early environment should be noted particularly. In those days the stars were still visible over the whole night sky to dwellers in all but the very largest cities; they were not hidden by sky-scrapers nor dimmed by the glare of arc-lights. So we find the boy, while still a small child, lying out in the open air in an old wagon bed, flat upon his back, on pleasant summer nights, watching the stars. He made friends with them and learned to trace and to recognize their apparent configurations long before he knew the name of a star or of a constellation, and long before he had any conception of the nature of a star. He welcomed them when they came round each year as he would welcome friends returned after a long absence. "Even to this day," he wrote in 1907, "this same friendship for the stars still holds . . . The coming of the Pleiades, of Orion or of the Scorpion I hail each year with the welcome of a friend."

When Barnard was but nine years old, he undertook a task in which many boys had failed. This was to keep a





COMET BROOKS

Photographs taken by E. E. Barnard, with the Crocker telescope, at the Lick Observatory. The left-hand photograph was taken on October 21, 1893, the right-hand photograph on October 22, 1893. Note the extraordinary change in the tail of the comet in the 24 hours between the dates of the two photographs

great enlarging camera on the roof of a photographer's studio constantly directed at the sun. Faithfulness and patience were the prime requisites for this work and these Barnard did not lack even as a boy. Indeed, he so fully justified the confidence placed in him that he continued to work in this studio —the Van Stavoren Gallery—for seventeen years, gradually becoming thoroughly familiar with every detail of the wet-plate photographic process.

Throughout these years, while working regularly in the daylight hours, earning part at first, and later the whole of the living for the family, his evening hours were given to study, under the guidance and inspiration of his mother, and to watching the stars. A sober, rather sad, life for a boy, one would say, but one which formed the best possible foundation for his later brilliant work.

It was inevitable, given such a character and such aspirations, that sooner or later the way would open to wider knowledge of the stars. What we, in our ignorance, are pleased to call chance brought it to pass that Mr. J. W. Braid, the operator in the Van Stavoren Gallery, who, I am happy to say, still lives in Nashville, should find on the street the small objective of a broken spy-glass, and should be moved to make a pasteboard tube for it, fit an eyepiece at the other end of the tube, and let Barnard have it for his first telescope. Somewhat later a stray volume of the works of Thomas Dick fell into Barnard's hands, and in this he found his first star map and from it learned the names assigned to the stars and constellations he already knew so well by his own observations. Another home-made telescope, with lenses (purchased this time) of $2\frac{1}{4}$ inches aperture, followed; and in 1876 he bought for $400 a 5-inch telescope, equatorially mounted, from John Byrne, of New York. What this purchase represented in self-denial on the part of the boy and of his mother can best be indicated by saying that the cost of the telescope equalled about two thirds of a whole year's earnings!

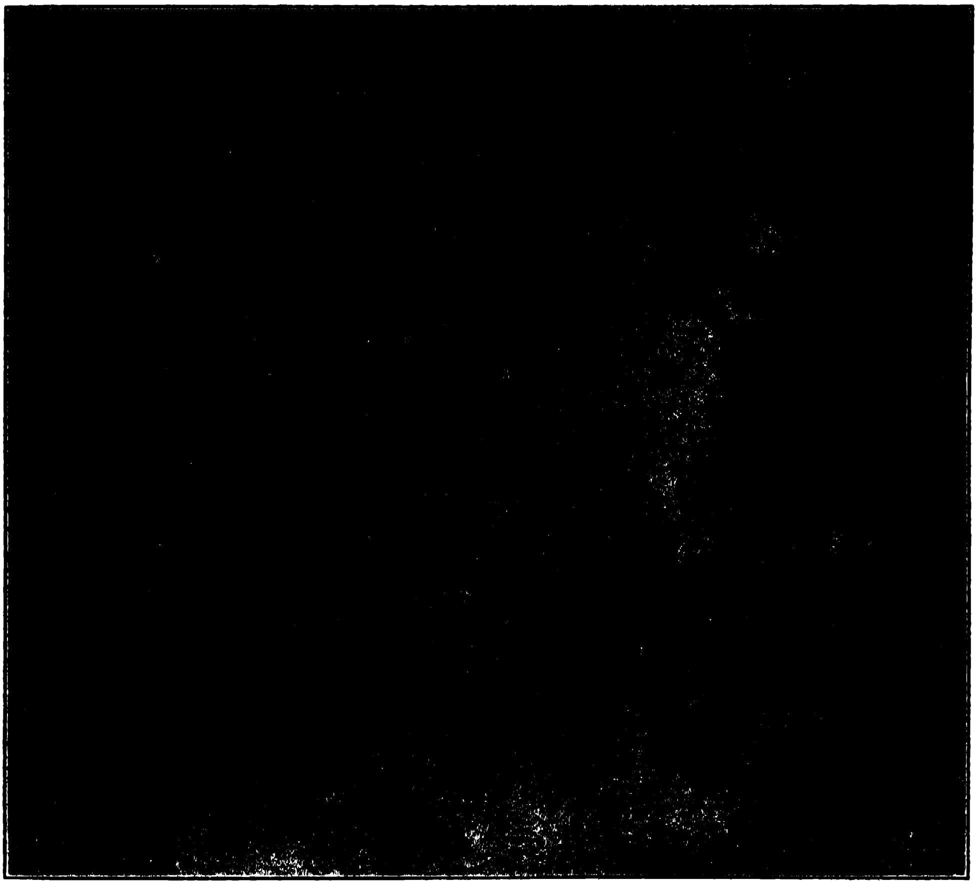
With a telescope powerful enough for really useful work, with a zeal for observation of the stars that had already given him a local reputation, and with the increasing knowledge gained by his reading and study, he was ready to join the American Association when it met at Nashville, in 1877, and to profit by the advice he sought from its president, Simon Newcomb, as to further studies.

The year 1877 thus brought him to a new stage in his career. He heeded Newcomb's assurance that training in mathematics was essential to his progress and in the half dozen years that followed, we find him redoubling his efforts, studying not only mathematics but other subjects and, for a time, even engaging a special tutor to assist him. The telescope, too, was kept busy, and with it he laid the foundation for that intimate knowledge of the aspect of the heavens in which he excelled all astronomers of his generation.

Then, in January, 1881, he married Miss Rhoda Calvert, who had come to Nashville from England with her brothers. They were artists who found work in connection with the studio where Barnard was employed. It was a happy and a fortunate marriage, and Mrs. Barnard helped him and encouraged him in his efforts to improve his education, and helped him also in the care of his invalid mother.

Four months later, on May 12, 1881, he found his first comet in the early morning sky. He saw it again on the following night but could not locate it thereafter, and, as he had not announced his discovery, it received no ranking in the formal records of astronomy. But it stimulated his interest, and he began to hunt for comets systematically.

It is possibly true, as some astron-



THE GREAT STAR CLOUD IN SCUTUM

PHOTOGRAPHED BY E. E. BARNARD, WITH THE BRUCE TELESCOPE, AT MOUNT WILSON, JULY 30, 1905; EXPOSURE 5^h 30^m. "THIS, THE GEM OF THE MILKY WAY, IS THE FINEST OF THE STAR CLOUDS," E. E. B. A NUMBER OF THE DARK MARKINGS ARE APPARENTLY PROJECTED AGAINST THE QUITE UNIFORM BACKGROUND OF FAINT STARS. NOTE PARTICULARLY THE ONE LEFT OF THE CENTER AND NEAR THE EDGE OF THE PICTURE. "IT LOOKS LIKE A SMALL, DARK COMET, WITH A TAIL CURVING TO THE NORTH." E. E. B.

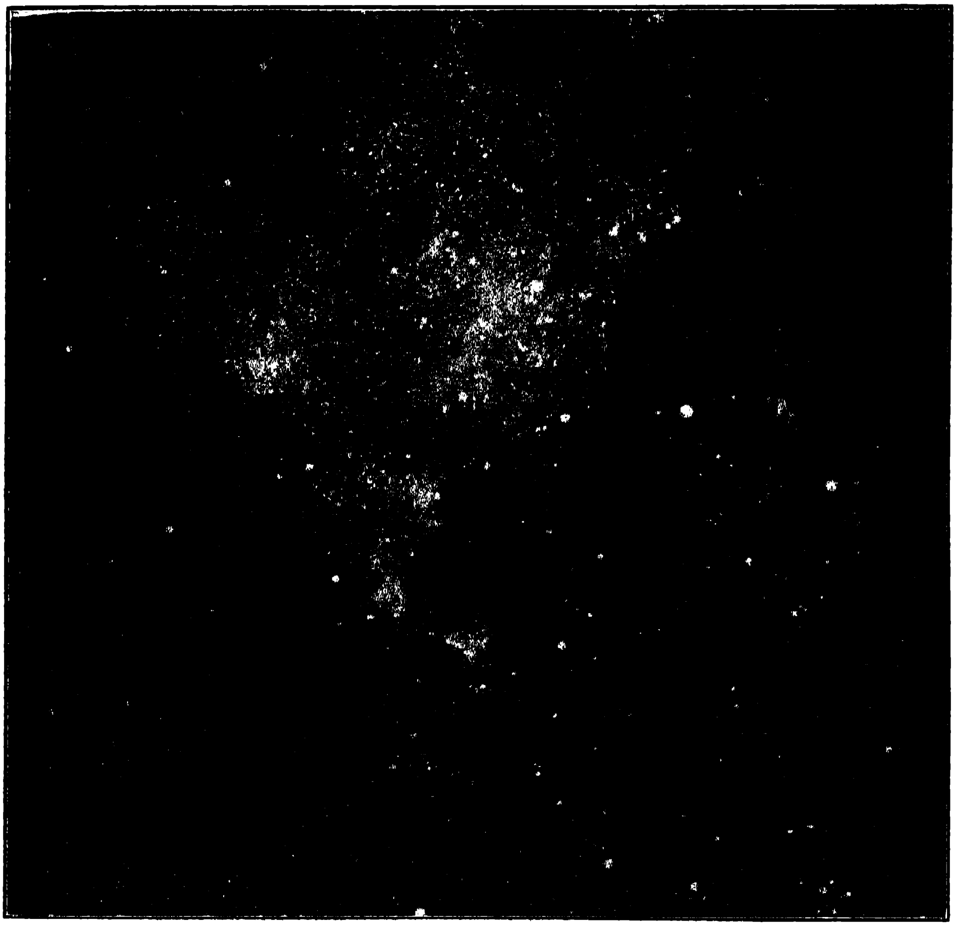
omers have rather scornfully said, that any one can find a comet if he will but look long and carefully enough. But that is a large "if." I recall that in my first years at the Lick Observatory, C. D. Perrine was searching for comets systematically. Evening after evening he swept the western sky, and morning after morning the eastern heavens, in such manner that he covered the entire night sky at regular intervals. Many a night he would come in to the 12-inch dome where I was at work and borrow the telescope to examine more carefully a suspicious looking object, only to find that it was a small nebula or a tiny cluster of very faint stars. In the comet-seeker these objects can be distinguished from faint comets which lack tails only because they remain relatively fixed, whereas the comet moves among the stars. It was not until he had given many months to such careful scrutiny of the skies that Perrine was rewarded by his first discovery and we, who knew of his careful, intelligent work, knew too that he had fully earned the credit that came from this, and from his later discoveries.

So with Barnard in those earlier days. On September 17, 1881, he found another comet and this time he sent word of the discovery to Lewis Swift, and through him to astronomers generally. This comet was therefore carefully observed and is known, in the annals, as Comet 1881 VI. The discovery had important consequences quite other than its bearing upon his reputation as an observer. Mr. H. H. Warner, of Rochester, New York, had offered a prize of $200 for each unexpected comet discovered by an American observer. This prize came to Barnard for the discovery of Comet 1881 VI. Mrs. Barnard felt that the money must be used for some definite purpose, and with her encouragement, and faith that later payments would be met "somehow," and that they would "manage," it was accordingly used as the first payment for a house. Faith, backed by hard work, had its due reward, for Mr. Warner's offer was continued for several years, and Barnard actually won enough prizes for cometary discoveries to pay for the "Comet House," as it is still known here in Nashville and to all astronomers.

By the year 1883 Barnard had made such progress in his studies that he was prepared to profit by the opportunity his reputation brought him. Friends who believed in him offered him a fellowship in Vanderbilt University. The stipend was but $300 a year and a house on the campus, near the observatory, but it was sufficient, thanks to Mrs. Barnard's courage and good management, to permit him to give up his studio work and to devote his entire time to his studies and to work at the observatory, which, with its 6-inch equatorial telescope, was put in his care. His name, therefore, appears on the rolls of the university as student, and also, in 1884–85 as assistant, in 1886–87, an instructor in practical astronomy.

In 1887, Barnard had completed a four-year course in the school of mathematics at the university, and though he did not at this time receive a degree, his record of cometary discoveries, his observations of Jupiter, his independent discovery, in 1883, of the Gegenschein—that feebly luminous patch of light that moves across the sky along the ecliptic, keeping always 180° from the sun—had given him such a reputation as a keen and reliable observer that Director E. S. Holden offered him a position on the staff he was organizing for the Lick Observatory, then nearing completion.

Forty years ago, therefore, at the age of thirty, Barnard had completed his apprenticeship and was ready to enter upon his career as a professional astronomer. As equipment for that career he brought an alert mind and a marvel-



REGION OF THE NORTH AMERICA NEBULA

PHOTOGRAPHED BY E. E. BARNARD, WITH THE BRUCE TELESCOPE, AT MOUNT WILSON, 1905, SEPTEMBER 4; EXPOSURE TIME 4^h 20^m. THIS WONDERFUL OBJECT "IS A SPLENDID MIXTURE OF STARS AND NEBULOSITY. ACCORDING TO WOLF, THE NEBULA IS GASEOUS. AROUND THE NEBULA ARE SCATTERED MASSES OF NEBULOSITY, LIKE ISLANDS OFF THE MAINLAND." E. E. B.

lously keen eye—a combination which produces what I like to call the "seeing" eye—a body inured to hardships, a thorough mastery of photographic processes, a sound knowledge of what had been done in astronomy, an intimate knowledge of the visible heavens, and, what was most important of all, an enthusiasm for observing that amounted to a passion. Speaking of this characteristic, Professor Frost writes, "To him, a night at the great telescope was almost a rite—a sacred opportunity for a search for truth in celestial places." And what was true of his work with the 40-inch Yerkes telescope was equally true of all his observational work.

The outward aspects of his later career need not long detain us, for, in the main, his life was the life of all astronomical observers; nights devoted to work in the domes, days given to development and examination of photographs, and to computations and the preparation of papers; with now and again a relatively short absence on an eclipse expedition or a trip to England; enforced interruptions to observing, while waiting, in 1887–88, for the completion of the Lick Observatory, in 1895–96 for the completion of the Yerkes Observatory; and one trying year, in 1914, when, under the doctor's orders, he had to give up work. It is worth while emphasizing, however, that rarely if ever, has an astronomer given such passionate devotion to his observational work as Barnard gave; a devotion that endured to the date of his last observation with the 40-inch on the night of December 21, 1922, less than two months before his death. Not cold, nor bodily fatigue, nor need for sleep could keep him from the telescope while the stars were shining.

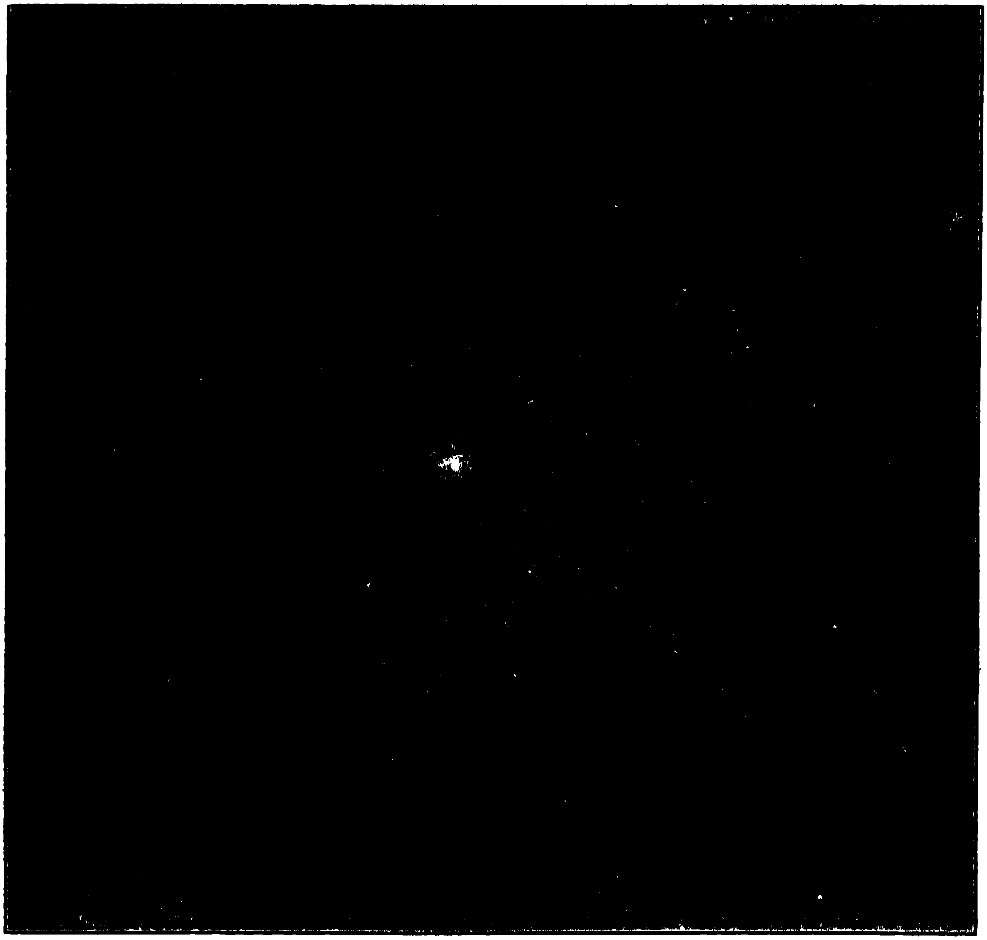
It is the record he made as an observer that now concerns us—and what an extraordinary record it is![2] Most of us specialize; we study the planets, or the sun, or variable stars, or double stars, or the nebulae. Barnard's specialty, as I have said elsewhere, may be said to have been the visual or photographic observation of every description of object known in the heavens!

At the Lick Observatory, he was at first assigned to work with the 12-inch refractor, the comet seeker and the small photographic telescopes. Naturally, he kept up his search for comets, and the tradition at the observatory is that there was not an instrument on the place (except the meridian circle) with which Barnard had not found a comet—either an unexpected object, or one whose return had been predicted. One of these discoveries was that of Comet 1892 V, on October 12, 1892, the first comet found by photography. In a sense it was an accidental discovery, for the plate had been exposed, not to hunt for comets, but to photograph the region of the Milky Way near Altair. The discovery, however, bears testimony to Barnard's care in developing and examining his plates promptly, and to his alertness in at once recognizing the nature of the object.

Another discovery worth noting here is that of a small, round, nebulous looking comet on September 2, 1888. Such an object, as I have said, can be distinguished from a nebula only by its motion among the stars. Barnard could not detect motion in this object during the time he held it under observation that night, but, as he wrote later, *from his thorough knowledge of that region of the sky*, he had no hesitation in announcing it as a comet!

Far more interesting and important.

[2] In the address, as delivered at Nashville, forty lantern slides were projected upon the screen, to illustrate Professor Barnard's work. The plates accompanying this article are from his negatives. I acknowledge, gratefully, the kindness of Director Frost, of the Yerkes Observatory, in permitting me to reproduce the photograph of the Milky Way. R. G. A.



REGION OF THE CLUSTER MESSIER 37 IN AURIGA

Photographed by E. E. Barnard, with the Bruce telescope, at Mount Wilson, 1905, March 31. Exposure $1^h\ 30^m$. Every white dot in the photograph, of course, represents a star. No luminous nebulae are visible on the plate, and Professor Barnard was in doubt as to the nature of "the curious black spot" about the size of the central bright cluster and to the right of it

however, were the photographic studies of comets, and of the rapid changes that take place in the form and structure of the tails of comets, which Barnard initiated with the Crocker telescope of the Lick Observatory and continued later at the Yerkes Observatory, as opportunity offered. In this field, as in the field of Milky Way photography, Barnard was a pioneer, and the many hundreds of photographs of comets which he secured (more than 1,400 at Yerkes alone) still offer a rich material for detailed studies. His photographs of Swift's Comet of 1892, and especially of Brooks' Comet of 1893, revealed for the first time the remarkable motions and changes in the tail of a comet produced by the stimulating and repulsive forces directed upon it by the Sun when the comet is near its perihelion point.

The Milky Way had always fascinated Barnard, and he undertook a systematic photographic exploration of it with the Crocker telescope at Mount Hamilton as soon as that instrument was ready. These photographs revealed for the first time the marvellous richness of the star clouds of the Milky Way and their complicated structure. Later, with the more powerful portrait-lens doublet telescopes provided at the Yerkes Observatory through the generosity of Miss Catherine Wolfe Bruce, he continued these studies to better advantage. He also transported the Bruce telescope to Mount Wilson, in 1905, to photograph from that favored location the more southerly portions of the Milky Way that could not be seen well, if at all, from Williams Bay.

His earlier work at Mount Hamilton on the Milky Way and on comets has been published as Volume XI of the Publications of the Lick Observatory, and at this very time the Yerkes Observatory is distributing the "Photographic Atlas of Selected Regions of the Milky Way," whose publication has been made possible by a grant from the Carnegie Institution and by the skill and devotion of Mrs. Barnard's niece, Miss Mary Calvert, and of Director Frost. Professor Barnard himself passed upon every plate included in the earlier volume, and not only made the printing negatives for the fifty-one photographs included in the later work, but personally inspected and selected every one of the 35,700 prints for the edition of 700 copies.

This is not the occasion for a critical review of either of these books, and, indeed, it is necessary to examine the plates and prints themselves one by one, with the aid of the notes added by Barnard himself and by his editors, to appreciate fully the beauty of these photographs and their significance. Here it will be sufficient to direct attention to one or two features.

Every photograph shows such a crowded field of faint stars that it gives the effect of star clouds; but the distribution of the stars is not uniform and in many places there are great areas of true nebulosity. There are also innumerable dark lanes and what appear to be "holes" in these clouds, and these dark markings in particular attracted Barnard's attention. It is clear that at first he took them at their surface value and regarded them as vacant spaces. As time went on and he considered the question more carefully, studying minutely the details revealed on the ever-growing number of his photographs, his views gradually changed and he became convinced that here we have to deal, not with vacant regions, but with vast accumulations of matter that absorbs or occludes light, an interpretation which was offered by A. C. Ranyard as early as 1894. This is, of course, the view that is held by astronomers generally at the present time, and that it is correct will be fairly obvious to any one who studies carefully

NEBULOUS REGION IN TAURUS

PHOTOGRAPHED BY E. E. BARNARD, WITH THE BRUCE TELESCOPE, YERKES OBSERVATORY, 1907, JANUARY 9. EXPOSURE $5^h\ 29^m$. PROFESSOR BARNARD WRITES: "VERY FEW REGIONS OF THE SKY ARE AS REMARKABLE AS THIS ONE. THE PHOTOGRAPH . . . BEARS THE STRONGEST PROOF OF THE EXISTENCE OF OBSCURING MATTER IN SPACE"

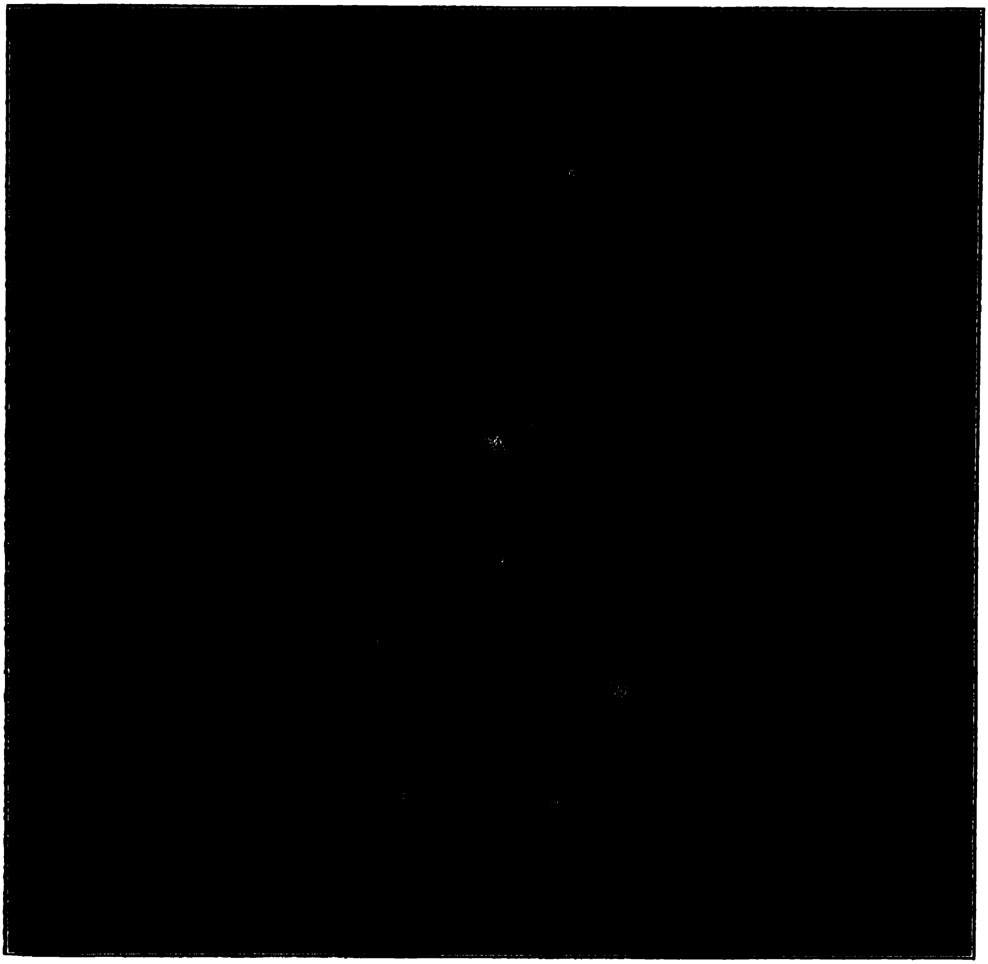
the large scale photographs taken with the powerful reflectors now available—and, in particular, those taken in recent years with the 60-inch and 100-inch reflectors on Mount Wilson. In many instances one is driven to the conclusion that light from the more distant objects in or near the galactic plane is obstructed by dark nebulous matter; in many others it is clear that the structure of the nebula is the same whether it shines or is revealed merely by contrast with its luminous background. To borrow Bessel's remark about the stars, the power to emit light, we believe, is not a necessary attribute of a gaseous nebula; indeed, this power, it is probable, does not originate in the nebula at all, but in the white hot stars enmeshed within it. Where these are lacking, the nebula does not shine.

Barnard himself called attention to the similarity in structure between luminous and dark nebulae, and his work did much to extend our knowledge of objects of the latter category, especially in the Milky Way. In fact his catalogue of these objects is, I think, the most extensive one we have.

I have dwelt first upon Barnard's work in comet discovery and in the photography of comets and of the Milky Way, because these lines of activity are most closely associated with his apprentice work in his early days at Nashville. But I believe, with Professor Frost that, devoted as Barnard was to work of this kind, and successful as he became in it, his great love was for visual observation with the powerful refractors that he had the privilege of using. He was first and foremost a keen-eyed observer. This was foreshadowed by his cometary discoveries at Nashville and his independent discovery of the Gegenschein, but was dramatically revealed to the astronomical world by his discovery of the fifth satellite of Jupiter with the 36-inch Lick refractor on September 9, 1892.

Jupiter had engaged his attention from a very early date, and one of his first contributions to the "Publications of the Astronomical Society of the Pacific" was a paper on his visual observations of the planet with the small telescopes he used at Nashville—and with the 12-inch telescope at Mount Hamilton. At first, naturally, as junior member of the staff, he had no opportunity to use the larger telescope. When this opportunity did come, he promptly utilized it to study Jupiter, then well placed for observation. He studied the planet's surface with keen attention, and also the sky in its immediate vicinity, with the definite purpose of ascertaining whether any satellites besides the famous four first seen by Galileo existed. When, on Friday night, September 9, 1892, he saw a tiny point of light close to Jupiter—so faint that the planet itself had to be thrown out of the field of view to permit it to be seen—he suspected its true character at once, but aside from communicating his suspicions in a letter to his good friend, Professor S. W. Burnham, then at Chicago, he said nothing about it until he was able to see the object again on the following night and to measure its motion outward to elongation and back toward the planet. His long series of measures in the following months and years established the period of the satellite with high accuracy, and the other orbital elements as well, and brought out the extraordinarily rapid motion of the line of apsides of the orbit produced by the perturbations to which the tiny body was subject.

This was but one, though, no doubt, the most brilliant of the results of his visual observations and measures of the planets and satellites of our system. Another striking observation, for example, was that of the eclipse of Japetus, the eighth satellite of Saturn, by the ring system of the planet in November, 1889. He saw the satellite through the so-called crepe ring, thus establishing



REGION OF THE GREAT NEBULA OF RHO OPHIUCHI

Photographed by E. E. Barnard, with the Bruce telescope, at Mount Wilson, 1905, April 5. Exposure time, 4^h 30^m. "The region of Rho Ophiuchi is one of the most extraordinary in the sky. The nebula itself is a beautiful object. With its outlying connections and the dark spot in which it is placed, and the vacant lanes running to east (left) from it, it makes a picture almost unequalled in interest in the entire heavens." E. E. B.

the fact that this ring is really transparent, and supporting Clerk Maxwell's famous conclusion that the rings consist of a swarm of innumerable tiny particles.

During the later years of his residence on Mount Hamilton, he carried out with the 36-inch telescope a long series of micrometrical measures of the diameters of planets and of satellites and of a few of the larger minor planets. The great accuracy and completeness of these measures gave them high value and to this day they set a standards for work of this character.

His long series of accurate measures of comet positions also demand mention. He was accustomed to follow any comet that he observed just as long as he could possibly see it with the 36-inch or 40-inch refractor, and his measures, in many instances, continued long after every other observer had abandoned the object as too faint to measure.

His visual observations, moreover, were by no means confined to bodies in the solar system. Double stars, variable stars, novae, star clusters and the nebulae all claimed his attention. Certain double stars he followed more systematically than did any other observer, and in the years covered by his observations it would suffice to depend upon his measures alone, discarding all others. I may cite Krueger 60, as a striking example, for I computed the orbit of this interesting binary system only a few years ago. I utilized all available measures, of course, but Barnard's measures from 1900 to 1921 were so numerous and so consistent that they practically determined the observational curve for this period.

Barnard's skill as a visual observer was also demonstrated by his determination of the parallax of Krueger 60, for his value, derived from micrometer measures, agrees with the best modern photographic results well within their probable error.

It would unduly prolong my address were I to refer to all of Barnard's interesting observations and discoveries, but I must include at least two others, the first being his measures of the expanding nebulous ring, or shell surrounding Nova Aquilae, No. 3, the remarkably brilliant new star which suddenly appeared on the night of June 18, 1918, and which was independently discovered by many watchful observers, Barnard himself being one of them. His measures of the nebulous envelope indicated that it was expanding, a fact which was fully confirmed by measures at Mount Hamilton with the 36-inch refractor, and by spectrographic observations. This has been shown by Hubble's photographic investigations in the present year still to continue, at a practically uniform angular rate, though the nebulous disk is now too faint to be measured visually.

The other discovery that must be referred to is that of the famous "run-away" star that will always be known as "Barnard's Star," for aside from its intrinsic interest, it gives a hint of the discoveries that may still be made in the course of the thorough examination of his great store of negatives that is now in progress at the Yerkes Observatory Incidentally, too, it illustrates one of the great satisfactions that we find in careful astronomical observations, whether visual or photographic. The measures, or the photographs, may be made with one particular object in view; years, or decades, or centuries later they may be utilized to further our knowledge in ways of which the observer had not dreamed.

Barnard himself was so absorbed in the work of actual observation, either at the eye end of the great 36-inch and 40-inch refractors, or with the Crocker and Bruce photographic telescopes, that he was not able to give his photographic plates any exhaustive study. Indeed, he did comparatively little in the way of measurement of photographic plates,

DARK MARKINGS NEAR THETA OPHIUCHI

PHOTOGRAPHED BY E. E. BARNARD, WITH THE BRUCE TELESCOPE, AT MOUNT WILSON, 1905, JUNE 5. EXPOSURE 4^h 45^m. NOTE THE DARK S-SHAPED MARKING NEAR THE CENTER AND THE STRANGE CURLED FIGURE A LITTLE ABOVE IT. ALSO THE GREAT DARK LAKE TO THE LEFT AND BELOW THE CENTER, WITH THE DARK LANE RUNNING FROM IT TO THE RIGHT. CONTRAST THESE WITH THE STAR CLOUDS IN OTHER PARTS OF THE PICTURE

and it is doubtless true, as Professor Frost says, that he regarded his plates more as pictures of the heavens than as material for detailed measures. Occasionally, however, he did compare two plates of the same region, taken at different times, under the comparator, and such a comparison of a plate taken in August, 1897, with the Willard lens at Mount Hamilton, with one taken with the Bruce telescope at Williams Bay in May, 1916, revealed a faint star in Ophiuchus, having an annual proper motion of 10″.3, the largest known, even to-day. Such remarkable motion—rapid enough to produce in a single month a displacement measurable with our great modern telescopes—led at once to the inference that this star is one of our nearest neighbors, and investigations proved, as a fact, that its parallax is 0″.538, making the star second only to the system of Alpha Centauri in point of proximity to the sun. It is therefore intrinsically faint, though not nearly so faint as the third nearest star, Wolf 359, which van Maanen's recent measures have proved to be by far the faintest of all known stars.

This rapid survey of Barnard's observational work is necessarily impressionistic and incomplete, but it is sufficient to indicate the extraordinary range of his interests and his amazing industry, as well as his ability to plan his researches wisely and his alertness of mind in detecting the significance of any phenomenon he observed, whether it were a point of light near Jupiter, a faint and hazy trail on a photographic plate, or a halo about a bright star.

It must be kept in mind that Barnard served his astronomical apprenticeship in the days when the new astronomy, as it has often been called, was in the very infancy. Even in 1887, when he went to the Lick Observatory, this statement would hold. The parallaxes of very few stars had been measured; a little, but only very little, was known about the spectra of the stars; a few attempts, not very successful, had been made to measure, visually, the radial velocities of stars; a beginning, but merely a beginning, had been made in astronomical photography, and practically nothing was known of the stars as organisms.

Barnard's training did not fit him to engage successfully in spectroscopic observation and research, but it did enable him to become one of the great pioneers in astronomical photography. His photographs of comets have never been excelled; his photographs of the Milky Way structure are surpassed, in detail, only by the large scale plates taken with the great modern reflectors; his photographs of planets—of Mars in particular—were equal to the best that had been made up to the time of his death.

It was but natural, however, that he should find his greatest satisfaction in direct visual observations and measures with the powerful refractors he had at his command, for he was first and foremost an observer. He had the seeing eye. This is shown by his astronomical work, but was also evident from his delight in the observation of animals, birds and trees. In other circumstances he would have won renown as a naturalist.

Membership in the National Academy of Sciences, and in many other societies of the highest standing at home and abroad, honorary degrees from colleges and universities; medal awards by academies and societies in France, in England and in America, all attest the widespread regard and respect for the man and for his work. Barnard, the greatest astronomical observer of his generation, was honored throughout the scientific world; Barnard, the modest, simple-minded, unselfish, kindly man, was loved by every one who knew him.

THE PROGRESS OF SCIENCE

THE SCIENTIFIC WORK OF THE SECRETARY OF THE SMITHSONIAN INSTITUTION

THE distinguished line of succession in the secretaryship of the Smithsonian Institution—Joseph Henry, Spencer F. Baird, S. P. Langley and Charles D. Walcott—has been continued by the election of Dr. Charles Greeley Abbot, who has been acting secretary since the death of Dr. Walcott a year ago and has been identified with the work of the institution for thirty-three years.

Dr. Abbot was born on a New Hampshire farm, in 1872, and graduated from the Massachusetts Institute of Technology, where he worked especially with Professor A. A. Noyes. In 1895 he went to the Smithsonian as assistant to Professor S. P. Langley in the Astrophysical Observatory. Langley was at that time trying to plot the Fraunhofer lines in the invisible infra-red spectrum, with the aid of his bolometer, but instruments were not yet delicate enough. Dr. Abbot improved the setting of the bolometer and the bolometer itself. He eliminated very largely the effect of earth jarring and trembling and temperature effects. The resultant plotting of the infra-red spectrum is the classic work on the subject.

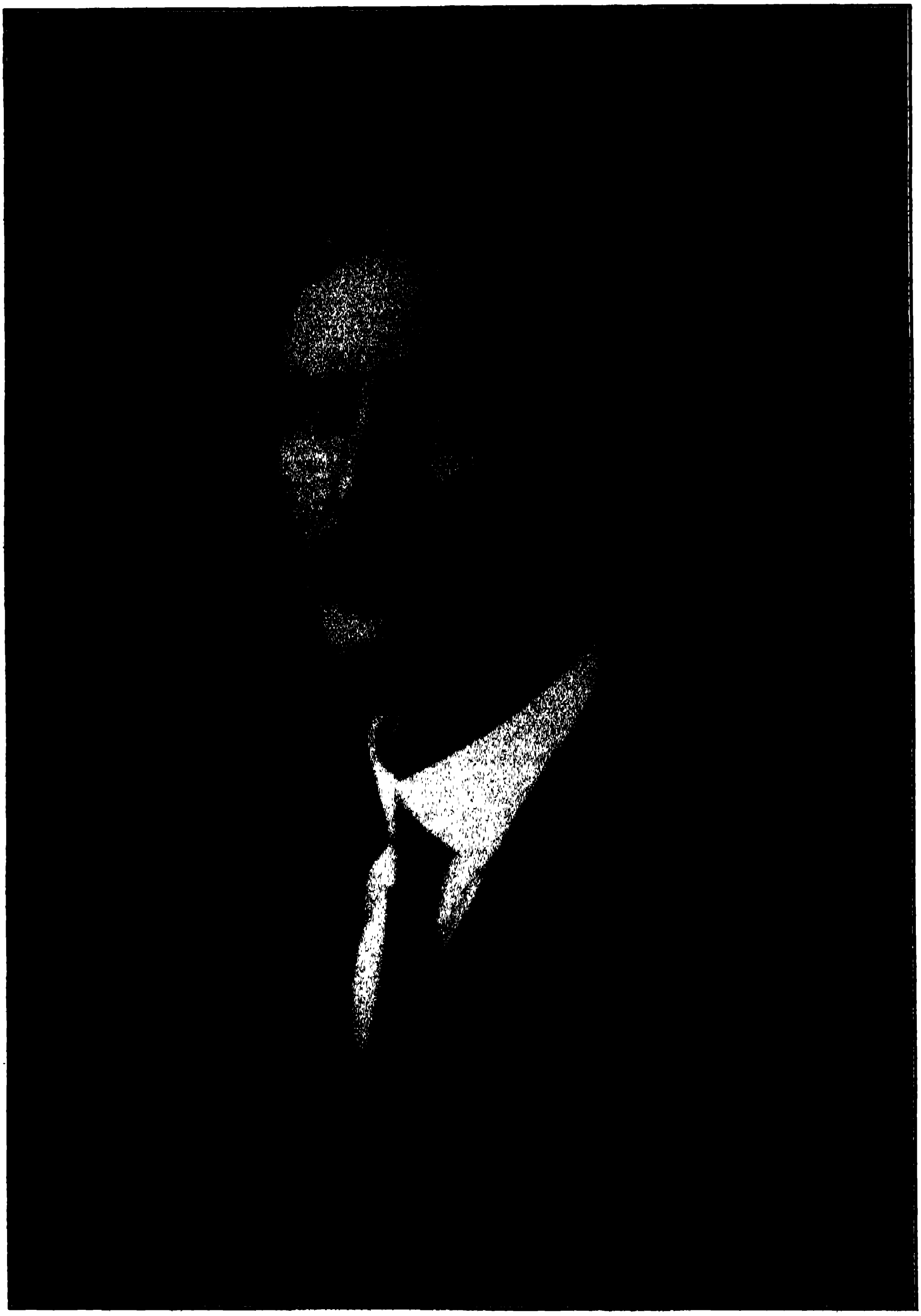
In 1902 Professor Langley and Dr. Abbot began their work on the intensity of the radiation of the sun. Until 1907 Dr. Abbot made solar constant measurements at the Smithsonian Institution in Washington. With the establishment of the Carnegie Observatory on Mt. Wilson in 1905, its director, Professor George E. Hale, invited the Smithsonian to send observers to measure the solar constant there.

In 1907 and 1910, while colleagues observed on Mt. Wilson, Dr. Abbot made complete solar constant observations on the extreme summit of Mt. Whitney at 14,500 feet. Almost perfect accord was found between the results at Mt. Wilson and Mt. Whitney, showing, when considered with Washington observations, that from sea level to an elevation of nearly three miles, the Langley method, as perfected and practiced by Dr. Abbot, gave results independent of the altitude of the observer.

Dr. Abbot now undertook still another test. Apparently the sun varied. Were the variations really solar, or were they brought about by obscure atmospheric sources of error not yet eliminated. To test this question, he went to Algeria. There in 1911 and 1912, while his colleagues measured at Mt. Wilson, Dr. Abbot took observations. The results of the two stations accorded so well as to strengthen the conclusion that the observed variation was not being caused by local atmospheric conditions.

In 1913 and 1914 another experiment was made to prove that the means used to eliminate atmospheric influences were sound. Special recording pyrheliometers were constructed for measuring the intensity of the radiation of the sun at the highest altitudes which could be reached by sounding balloons. In 1913 five such instruments were sent up from Catalina Island, California. All were recovered and all had readable records made at about 14,000 meters. The instruments were improved and in July, 1914, three were sent up from Omaha, Nebraska, to 15 miles above the earth, one of which was recovered with record intact and results which again supported the correctness of Smithsonian measurements.

By 1926 proof of variation was reached. The essence of this final proof lies in a



DR. CHARLES GREELEY ABBOT

ELECTED SECRETARY OF THE SMITHSONIAN INSTITUTION

comparison of measurements of solar radiation received at the earth's surface made by the pyrheliometer for groups of days when the atmosphere is practically identical. The resulting curves followed exactly the original curves made by the solar constant measurements for the same days.

In 1918, Dr. Abbot, by advice of Dr. Walter Knoche, selected a site for a permanent station near Calama, Chile, and installed instruments made at the institution, under the care of trained observers for the work. Funds were furnished to remove this station to Mt. Montezuma in the year 1920, by Mr. John A. Roebling, of New Jersey. In 1920 a second station was established at Mt. Harqua Hala, Arizona, by Mr. Roebling's generosity, and with further aid from him this was transferred to Table Mountain, California, in 1925. In 1926, with funds from the National Geographic Society, Dr. Abbot established a third station on Mt. Brukkaros, South West Africa. These three stations in different hemispheres are producing measurements which can be checked against one another to get results of very great accuracy.

RESEARCH IN PHYSICS IN YALE UNIVERSITY

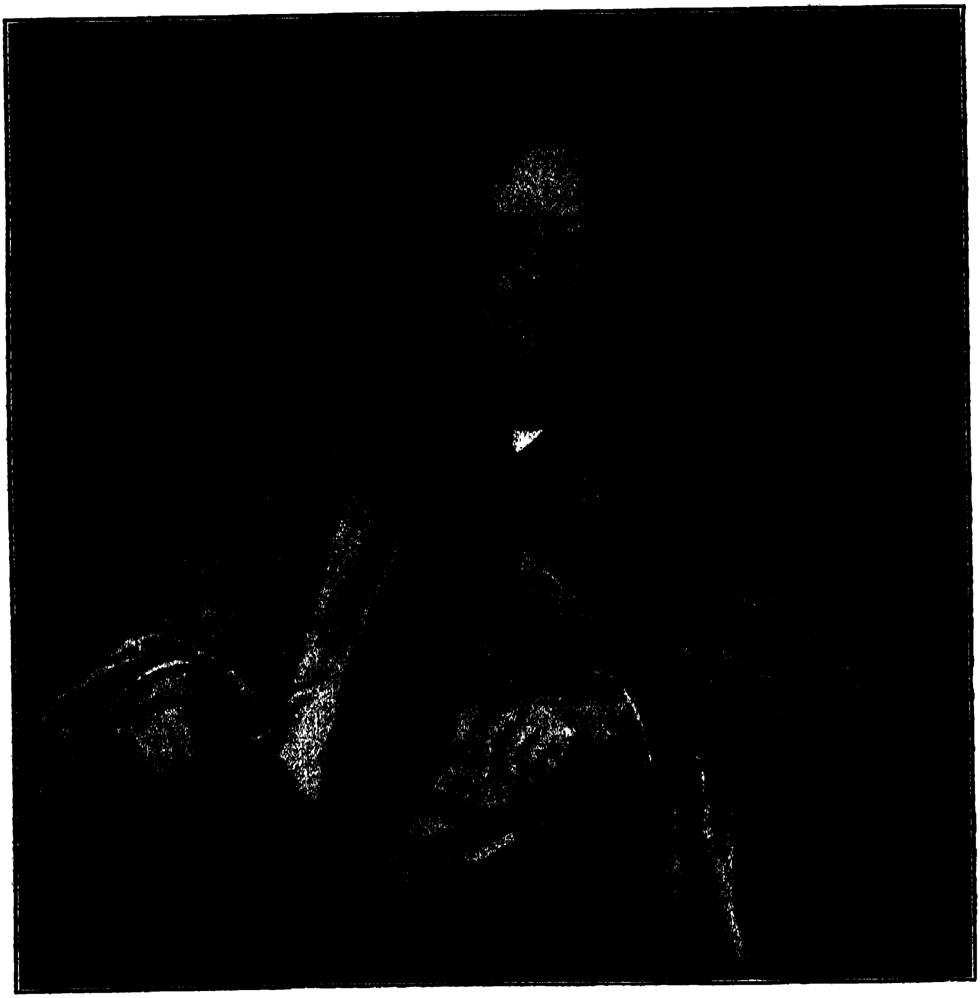
Yale University has made public a report on the research work being conducted in the Sloane Physics Laboratory, which gives an interesting survey of the work of a single institution in a single science.

Professor Louis W. McKeehan, director of the Sloane Physics Laboratory, is continuing during his first year at Yale his work on the "shape" of metal atoms, on which The Scientific Monthly has had the privilege of printing an article by him. The particular effect Professor McKeehan is now studying is the change in electrical conductivity due to elastic pull in fine wires. Graduate students under his direction are working on related problems. Another possible source of information about atoms in solids is found in studying their arrangement by x-ray methods. Dr. L. M. Kirkpatrick, who holds a Sterling fellowship, and several graduate students are working on researches in which x-rays and crystals are of principal importance.

Professor Alois F. Kovarik is continuing his study of the condensation of radio-active gases (radon and thoron) on cold surfaces, begun at Cambridge University two years ago. Besides this a study of alpha-ray straggling and another on the ratio of gamma-rays to the number of the disintegrating atoms from which they come are being undertaken by graduate students under Professor Kovarik's direction.

Dr. Ernest O. Lawrence, assistant professor of physics, and Dr. Jesse W. Beams are engaged in a series of researches into the times necessary for the appearance and disappearance of the effects of electric and magnetic fields upon the transmission of light. An idea of the precision possible can be gained by considering that changing the position of either cell by only a few centimeters along the ray of light, corresponding to a time difference of much less than a billionth of a second, produces an observable change in the transmitted light.

The new interest of chemists in the use of physical methods in attacking their special problems is shown by the fact that two of the spectroscopic problems under way in the Sloane Laboratory are being conducted by Dr. I. W. M. A. Black, Commonwealth fellow in the department of chemistry. The band spectra of certain organic compounds will, it is hoped, permit them to decide between various structures of the molecule which are equally probable in the



EDWARD BRADFORD TITCHENER

FROM 1891 UNTIL HIS DEATH PROFESSOR OF PSYCHOLOGY IN CORNELL UNIVERSITY, WHERE HE REPRESENTED THE BEST TRADITIONS OF THE ENGLISH AND GERMAN UNIVERSITIES. THE PORTRAIT IS FROM A PAINTING BY OLAF M. BRAUNER, PHOTOGRAPHED BY J. P. TROY

light of chemical evidence alone. This work and other spectroscopic problems are directed by Professor Horace S. Uhler. Dr. Lee Kinsey, who holds a National Research Council fellowship in physics, is also working with Professor Uhler on optical problems, particularly on the reemission of light from metal vapors under intense illumination.

Professor John Zeleny has just completed experiments on the striated electric discharges in gases. At moderately low pressures and under certain ranges of applied voltage the passage of the electric current through a gas in a long straight glass tube is rendered visible by the appearance at regular intervals along the tube of transverse layers of luminosity separated nearly by dark regions. Dr. Frank L. Cooper has also been measuring potential differences in a gas carrying an electric current. There is a spontaneous potential gradient in the atmosphere of such a kind that a small positive current is almost always flowing down from inaccessible heights to the earth's surface. The atmospheric potential gradient has sudden fluctuations of such magnitude that it may even change sign, and these changes, if enough of them can be correlated with changes in local, terrestrial or solar conditions, should give a clue as to the origin of the potential gradient.

Another almost cosmical problem has been attacked by Dr. Norman I. Adams, Jr., assistant professor of physics. The local broadcasting station found its reception interfered with by a distant station assigned to the same frequency band. The trouble was that the two frequencies actually used would differ by a frequency within the audible range and control is feasible.

Precision measurement of x-ray wavelengths, involving as it does the elimination of experimental errors, demands a very high order of technical ability. Dr. Charlton D. Cooksey, assistant professor of physics, and his brother, Donald Cooksey, have devised and constructed instruments of the necessary refinement.

Among the other members of the faculty who are engaged in experimental researches are George W. Gardiner, Jr., who is investigating the proportion of absorbed radiation which reappears in the energy of photo-electrons, and Joseph E. Henderson, who is trying to fix the angles at which soft x-rays of long wave-length suffer total reflection from various metals. This total reflection is one of the most interesting facts recently discovered about x-rays. Preliminary work on the critical angles for reflection was done two years ago by Professor Elizabeth Laird, of Mount Holyoke College, as a visitor in the Sloane Laboratory.

MUSIC FROM THE ETHER

Professor Leon Theremin, of the State Institute for Applied Physics at Leningrad, is exhibiting in the United States his remarkable apparatus and methods of producing music by manipulating electric waves. According to an article printed in the London *Times*, when an exhibition was given in the Albert Hall, London, in December, the apparatus may fairly claim to be a new musical instrument, unlike the other wonderful inventions which have in recent years impinged upon the art of music. It is a source of sound, not a medium of transmission or reproduction. It has in it, therefore, possibilities which the gramophone and wireless broadcasting can not claim. It is, however, as Sir Oliver Lodge pointed out, not a miraculously new thing, but a development of principles which are already understood and utilized in wireless.

PROFESSOR THEREMIN

WITH HIS NEW MUSICAL INSTRUMENT. ON THE RIGHT IS SIR OLIVER LODGE, THE EMINENT PHYSICIST, AND IN THE CENTER SIR HENRY WOOD, THE DISTINGUISHED MUSICIAN.

It is known that the frequency of a thermionic valve oscillator can be varied by moving the position of an earthed conductor in the vicinity of the set. Broadcast listeners are familiar with the howl which proceeds from a loud-speaker of a set adjusted with too strong reaction. In such a case the frequency of the note emitted by the loud-speaker is equal to the difference in the frequencies of the transmitting station and the locally generated oscillations in the receiver. In badly designed sets this howl can be made to vary in pitch by moving the hand in the vicinity of the tuning condenser. Since the human body is earthed the hand acts like a condenser plate, so that moving it is equivalent to changing the tuning condenser.

In Professor Theremin's apparatus the musical beats caused by two high-frequency oscillations of neighboring frequencies are controlled by this hand-capacity effect, the pitch being increased when the operator's right hand is made to approach a vertical metal rod connected to one of the oscillating circuits. The fact that the note increases in pitch as the hand nears the rod seems to give the explanation of the way in which the oscillators are so easily controlled. It was discovered some years ago that two high-frequency oscillators could be locked or synchronized so as to maintain identical frequencies and so give no beat notes. Professor Theremin appears to start with his oscillators in this condition, for there is no audible note produced by his apparatus until his

right hand reaches a certain critical distance from the rod. When this critical distance is reached the two oscillators break step, as it were, and a beat note is produced which increases in frequency as the hand is pushed nearer the rod and the two sets put farther out of tune.

The control of the loudness of the emitted note is also carried out by a similar hand-capacity effect, but here the application of oscillating valve principles is not so clear. There are various ways in which it could be done, the most simple being an alteration of phase between two component oscillations of approximately the same amplitude. When the oscillations were in-phase a loud note would be produced, and when they were out-phase silence would result.

Professor Theremin thus describes his methods:

By using an alternating current of suitable frequency tones of varying pitch are easily obtainable. A small vertical rod is used as the antenna. When the instrument is in operation electro-magnetic waves of very weak energy are generated around this rod. These waves are of a definite length and frequency. The approach of a hand, which is an electrical conductor, alters the conditions in the electro-magnetic field surrounding the antenna, changes its capacity and thus affects the frequency of the alternating current generated by the apparatus. In this manner a kind of invisible touch is produced in the space surrounding the antenna, and, as in a cello, a finger pressing on a string produces a higher pitch as it approaches the bridge, in this case also, the pitch increases as the finger is brought nearer the antenna.

Likewise the intensity of tone can also easily be changed by a simple movement of the hand in space. For this purpose the instrument is equipped with another, in this case circular, antenna around which electro-magnetic waves are similarly formed. The approach of a hand toward this antenna causes a change in the oscillating circuit. This change is necessary in order to effect in the instrument a change in the degree of the intensity of the alternating current which produces the tone. Thus by raising the hand over the ring-shaped antenna the note sounded grows louder and by lowering the hand it grows softer, until it dies out in the softest pianissimo.

THE SCHOOL SERVICE BUILDING OF THE AMERICAN MUSEUM OF NATURAL HISTORY

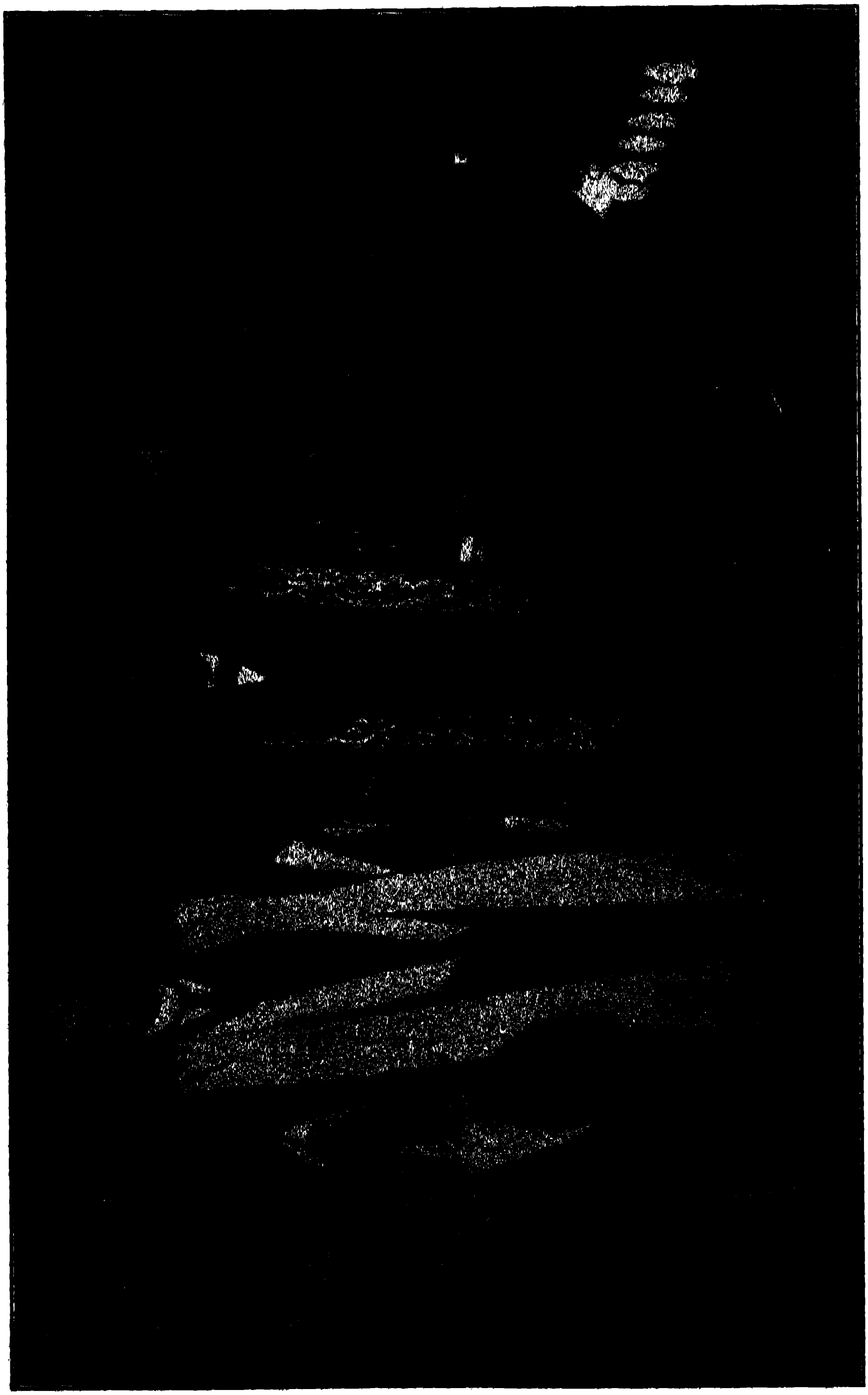
The American Museum of Natural History dedicated on the evening of January 17 the School Service building, a four-story addition to the museum, in which the educational program will be conducted in the future. About 400 educators and public men witnessed the dedication and the unveiling of a memorial statue of William Henry Maxwell, New York City superintendent of schools from 1898 to 1918.

The transfer of the School Service Building, as a gift of the city to the museum, was made by Walter R. Herrick, president of the park board, representing Mayor Walker. In accepting it for the museum, President Henry F. Osborn said that in no other city in the world was there any building comparable to this new school. He said the trustees and officers would do everything they could to give every school boy and school girl in the city the advantages such an institution affords.

The tribute to the late Superintendent Maxwell was the central feature of the evening's program. After a speech of presentation in which he characterized Mr. Maxwell as "a great administrator and inspired teacher of teachers," John Greene, president of the William Henry Maxwell Association, offered the statue to the museum.

All the lights were put out, and in the darkness a curtain which had veiled the statue, standing against the rear wall of the hall, was drawn aside. Then lights were thrown on the statue, revealing an impressive, seated figure of Maxwell of heroic size, cast in green bronze. He is represented sitting in flowing academical robes, on a massive throne.

"Although he did not teach, he had the parts of a teacher," said Dr. John



SIR ERNEST RUTHERFORD AND LORD HALDANE

PHOTOGRAPH TAKEN ON THE OCCASION OF THE OPENING OF THE LABORATORY OF PHYSICS OF THE UNIVERSITY OF BRISTOL. SIR ERNEST RUTHERFORD (WHO IS ON THE LEFT), CAVENDISH PROFESSOR OF PHYSICS AT THE UNIVERSITY OF CAMBRIDGE, AND LORD HALDANE, CHANCELLOR OF THE UNIVERSITY OF BRISTOL, MADE ADDRESSES AT THE DEDICATION OF THE LABORATORY, WHICH IS TO BE KNOWN AS THE HENRY HERBERT WILLS LABORATORY OF PHYSICS, IN MEMORY OF THE LATE MR. WILLS WHO CONTRIBUTED ABOUT A MILLION DOLLARS TOWARD THE COST OF THE BUILDING.

H. Finley, formerly New York commissioner of education, in describing the career and life work of Maxwell. "He knew good teachers when he saw them. He was a terror to others. He was essentially an administrator. He would have made a great governor or railroad president or engineer or president of a trust company.

"As it was, he was head of the greatest trust company in the world with a million parent depositors yearly and with assets, beyond all estimates, in the potentialities of from half a million to a million children. What a godsend it was that the young Scotch-Irish scholar had the fortunes of a half million of such millionaires in trust rather than the millions of dollars of the ordinary money millionaire!"

Other speakers were Dr. John J. Tigert, United States commissioner of education, who spoke on "Museums as National Assets"; Dr. William J. O'Shea, superintendent of New York City schools, who discussed "The Museum and the City Schools," and George H. Sherwood, director of the museum, who gave a lecture with motion pictures on "The American Museum's School Service."

Visitors inspected the new building at the close of the program. It consists of a basement and four floors, 160 feet by 90 feet on the first floor and 55 feet wide on the upper floor. The first floor contains an education hall, reserved for temporary exhibits. The second floor has a reception floor for classes visiting the museum. On the third floor are administrative offices, study rooms, library and activities connected with the extramural work of the museum. The fourth is the production floor, where photographs and negatives are cared for and the photographic studios are located.

To the minds of the authorities of the American Museum of Natural History, nature work is of primary importance in education Every year sees the educational program of the museum enlarged and to-day that institution is happily designated as "The Biggest Schoolhouse in the World."

The program of school service has the hearty endorsement of the Board of Education, superintendents and other school officials, but the conduct of the work is left entirely to the department of education of the museum, which is responsible for the institution's work with the schools. This action on the part of the school authorities has been an important factor in the success of the work because it has simplified it and brought the staff into direct touch with the teachers, which leads to a better understanding of our students' needs.

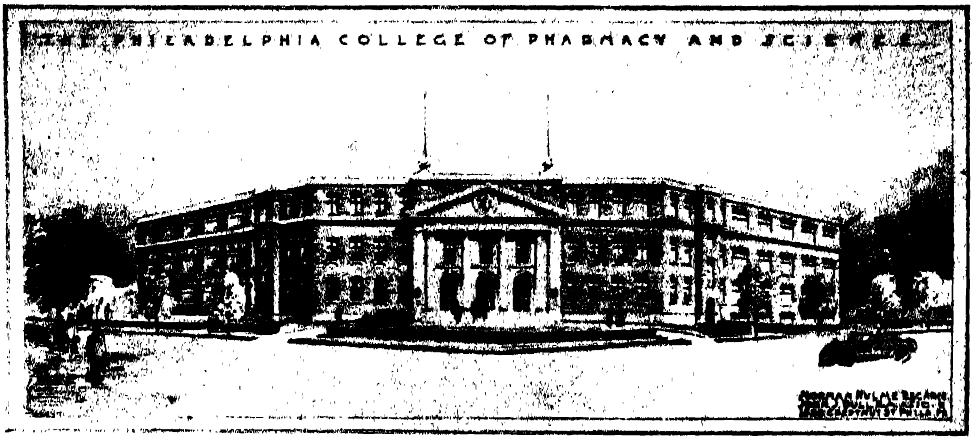
THE PHILADELPHIA COLLEGE OF PHARMACY AND SCIENCE

PHILADELPHIA's latest addition to the city's many institutions of learning, the new building for the Philadelphia College of Pharmacy and Science, has been completed and was occupied the first week in January.

The new college building is located at Forty-third Street and Kingsessing Avenue, not far from the University of Pennsylvania, and presents many unusual features not to be found in other educational structures.

The site is in one of the most charming locations in West Philadelphia, and convenient to the central part of the city by numerous trolley lines which pass within a square of the building. The building itself occupies the most commanding portion of the large tract around the college, and on one side faces a large city park. This park itself provides a beautiful setting for the college building, and in addition offers unusual recreational facilities for the students.

The architectural style of the building is colonial of the Georgian type. It is



constructed of reinforced concrete, faced with dark red brick laid in Flemish bond and trimmed with buff Indiana limestone. On the Kingsessing Avenue, or main front, the structure is three stories in height, while on the Forty-third Street side, the building is four stories high. On all four sides, unobstructed daylight for the class rooms and laboratories is always assured.

The main entrance is characterized by the use of a triple arched doorway formed with columns and pilasters, supporting a massive pediment on which is carved the college seal. Entrance gates of hand forged iron are used, ornamented with disks symbolic of the various branches of instruction—pharmacy, botany, science, chemistry, literature and mathematics. The walls of the vestibule and lobby are faced with limestone and marble, and the floors are Terraza and rubberstone tile. The main stairs are of marble, supported on metal risers. All the interior walls of the corridors and passageways are finished with a traventine wall treatment.

One of the unusual features of the building is that it is built entirely above ground, with no basement rooms. By reason of the angular form of the structure, it was possible to provide daylight in every room without resorting to light courts or light wells.

Throughout the building special consideration has been given to the question of acoustics The ceilings of the laboratories, class rooms and recitation rooms are covered with one half inch thick insulite wall board. This material was installed during the period of construction by putting it on the wood forms before the concrete was poured. As a result, excess reverberation has been eliminated, making it possible to use all the laboratories for lecture purposes. Sound transmission between rooms has been removed by the use of tile and the omission of communicating doors. To further put a stop to any noises which would affect classes, the corridors have been faced with a soft flooring material which excludes any noises made by the movement of bodies of students passing in the corridors.

To provide facilities for an assembly of twelve hundred students without unduly enlarging the building, an arrangement has been developed whereby three large lecture halls and the gymnasium are grouped together. These three lecture halls, seating three hundred each, with their tiered seats, face in an angular fashion the floor of the gymnasium, and by an arrangement of mechanically operated curtains, the halls may be thrown into one large hall, forming an amphitheater type of auditorium. Norman Hulme, R.A., of Philadelphia, was the architect.

THE SCIENTIFIC MONTHLY

APRIL, 1928

THE CHEMICAL ELEMENTS INDISPENSABLE TO PLANTS

By Professor CHAS. B. LIPMAN
UNIVERSITY OF CALIFORNIA

It is a reasonable assertion that the properties of matter, animate or inanimate, are functions of the chemical constitution of the substances which they characterize. By chemical constitution I do not mean composition in the analyst's sense of that term, but the quantitative and qualitative structures to which the atoms of the chemical elements composing them contribute. Biologists seldom, and laymen almost never, are aware of the important rôle played by the patterns into which the chemical elements are cast in determining the properties and characteristics of the chemical compounds. Much less perhaps do they appreciate this same fact in its application to the properties of living matter. This is brought vividly to the mind's eye by the reflection that the atoms of even one element alone according to their arrangement in the molecule confer various properties on the molecule. One needs only remember how strikingly different in properties are diamond and graphite to apprehend the momentous differences which the mere arrangement of atoms in the molecule of one and the same element determines.

If one next considers the possibilities open for the arrangement of different atoms in a molecule of a compound of two or more elements he becomes aware of the stupendous variety of substances with widely varying properties which can thus be created. Here we have opportunity for producing substances of different properties not only through different arrangements of the same number and kinds of atoms but through different arrangements of different atoms in different numbers. When one remembers further that there are known some eighty odd chemical elements the possibility of having virtually limitless numbers of chemical substances with markedly different properties becomes bewildering in its gigantism much as our imaginations find themselves reeling in the attempt to comprehend the concept of the infinite or what is tantamount to the infinite space in which the universes are suspended.

It is necessary to grasp the full significance of the foregoing statements in order that one may in turn appreciate the rôle played by the chemical elements in the life and growth of organisms as limited in this paper to the field of the higher green plants only. But before I address myself to a discussion of the subject of this paper directly, it is well to emphasize again what I have said in the foregoing paragraphs by applying the same concepts to the question of the structure and function of plant substance. If the arrangement of atoms of the same kind in a molecule is so strik-

ing a determinant of the properties of the substance thus constituted, if arrangements of two or more different kinds of atoms multiply and diversify enormously the possibilities for such striking results, it is not difficult for the imagination to conceive how the arrangement of the atoms in the very complicated and diversified substances of plant protoplasm may become the chief determinant of the properties of that protoplasm whose properties are but the algebraic sum of the properties of its constituents. It must follow from the foregoing that every type of living cell in order that it may continue to live and grow must be supplied with a certain number of different chemical elements which must contribute to such arrangements or patterns with one another as will determine the production of the substances without whose existence the cell can not carry on the work characteristic of it inclusive of the tasks of repairing waste and of growing.

For such purposes as those described above it is not only possible, but we have some evidence that certain plant organisms may require chemical elements with which other plant organisms can dispense, but it seems beyond a peradventure true that all higher green plants require in common certain chemical elements as an absolute condition of life and growth. Until very recently and for about three quarters of a century or more the scientific world has believed that these elemental chemical requirements common to higher green plants were limited to ten of the chemical elements as follows: oxygen, hydrogen, carbon, nitrogen, sulphur, phosphorus, calcium, magnesium, potassium, iron. Several years ago Mazé, at the Pasteur Institute in Paris, published experiments which seemed to cast serious doubt on the concept of the adequacy of the aforementioned chemical elements to the life and welfare of plants. By growing plants under controlled conditions respecting purity of chemicals and water used in culture solutions Mazé was able to show that plants can not live or maintain a normal appearance with only the ten elements named supplied to them in adequate quantity. By addition to the culture solution which constituted the medium of plant roots in his experiments, of such elements as boron, zinc, manganese and others besides the elements known to be essential he succeeded in making plants grow normally whereas they would not do so in the absence of such elements. He pointed out that only small quantities of such elements were required by plants but that such small quantities were absolutely essential. The botanical world as a whole regarded Mazé's experiments with much skepticism, however, and further work was necessary to convince plant physiologists of the truth and cogency of his conclusions. In 1922 McHargue furnished results of extensive experiments carried on in both sand cultures and solutions which left no doubt whatever that manganese is an essential chemical element to the growth of many if not all of the higher green plants. He made it clear that manganese is required in such small quantities relatively to other chemical elements known long ago to be essential that the fact of its essential nature could only be discovered by carefully freeing the root medium of manganese and that even then it was essential to grow the experimental plants well along toward maturity in order to determine if a lack of manganese influences their growth and life. There can be little doubt from the experiments described below that if the root media employed by McHargue had in fact been freed of every trace of manganese the striking effects which he noted would have manifested themselves much earlier. The next series of experiments published, which confirmed the contentions of Mazé, were those published by Miss Warington, of the Rothamsted Experimental Station in

England. In these experiments Miss Warington proved conclusively that the Windsor bean could not grow in a root medium devoid of boron. She regarded it as a special case and did not then see the general bearing of her results on higher plants in general. Nevertheless, the finality of her conclusion respecting the indispensable nature of boron to the Windsor bean is beyond question.

Several years ago Dr. A. L. Sommer, then a graduate student in the author's laboratory, undertook for her doctoral dissertation a study of the question of whether or not the elements aluminum and silicon are essential to the growth of higher plants. While she encountered many difficulties in devising adequate technique for insuring the exclusion of aluminum and silicon from the root medium (the culture solution in which the plants were grown) her published results leave little room for doubt that the essential nature of those two elements for some plants at least is clearly indicated. These results, however, did not partake of the finality characteristic of the results of McHargue and of Warington.

With all this evidence before him the author became convinced that the scientific world lacked the actual facts respecting the number and kinds of chemical elements which are really essential to plants. Realizing, moreover, that faulty technique was responsible for the earlier conclusions he determined upon an extensive program of study for the discovery of as many of the facts in the situation as possible. For the purpose of such a study he was supplied with a grant from the research fund of the University of California and engaged Dr. Sommer as a research assistant to continue the work begun by her on silicon and aluminum and to search for the facts in that regard respecting zinc, copper and other elements.

The results of some of these new experiments were published by Dr. Sommer and the author in detail in *Plant Physiology*. There we demonstrated, as Dr. Sommer has further shown in a paper which she published in *Science*, recently, that both boron and zinc are essential to the life of widely different species of higher plants, thus confirming the conclusions of Mazé and of Miss Warington, but making the latter author's conclusion of wider application. These results were made possible through a refinement of technique which required much patience and perseverance and for which Miss Sommer alone deserves credit. The plants were grown in culture solutions in glass containers of adequate size and form. These culture solutions were prepared with twice distilled water and with chemicals which were specially synthesized for the purpose or carefully recrystallized from chemically pure compounds purchased in the trade. Wherever possible the part of the seed remaining after the young seedling had sprouted was removed therefrom so as to remove as much as possible of the stored supply in the seed of the elements under study. Germination was carried on under great precautions in a medium which precluded absorption of the elements not desired. The cultures were grown in a specially constructed compartment in a greenhouse in which as little dust as possible was permitted to enter. "Soft" glass fruit jars were used in the experiments in which it was desired to exclude boron since that glass contains less boron than the "hard" glass of Pyrex jars. In other cases Pyrex beakers were employed which contained little soluble impurities aside from boron. Wherever possible the cultures were grown to maturity. As controls on the cultures grown without a given element, other cultures were prepared with ordinary chemically pure salts not recrystallized and with pure salts to which the element under test had been added. Realizing that the absence of extremely small quantities of other

elements as yet unstudied but possibly essential might vitiate the results small quantities of several of the elements found in plant ash were added even though their essential nature still remains unestablished.

The results of these experiments showed that in most cases plants can only make meager and that abnormal growth in the absence of zinc or of boron. In other cases fair growth is accomplished for a time but in a few weeks the plants fail in the absence of either one of these two elements, everything else being present in adequate quantity. If in the latter case a small quantity of the missing element is supplied to the cultures the plants recover and grow normally. But in many cases plants make no growth at all in a root medium devoid of either zinc or boron. The next very striking thing to observe is how small a quantity of a certain element makes the difference between life and death in the plants tested. One quarter to one half a part of zinc or of boron per million parts of the solution in which the plant roots grow is frequently enough to insure normal plant growth. The absence of such very small quantities of either of those elements prevents growth. It is of the greatest importance to note, however, that the quantities mentioned are in no sense the absolute requirements of plants for the elements in question. They are merely indicative of the general magnitude of the requirements in such cases. With greater refinement of technique such as preventing the introduction of any dust, the more complete removal of the stored material in the seed, the greater purification of water and chemicals, and lesser solubility of the glass the quantities actually essential of the elements in question might perhaps have to be enlarged. All this does not, however, alter the conclusion that the ordinary technique of culture solution experiments, however fine it may appear, is not always equal to the task of discovering whether or not a certain chemical element is essential to plants, for certain elements may be needed in such small quantities that only the very special technique above described can reveal to us their real status in the life of the plant. It is even possible that still other chemical elements are needed by plants in such extremely small quantities that we shall find ourselves unable to devise adequate technique to discover and prove their indispensable nature. Extremely small quantities of certain chemical elements are adequate and alone equal to performing certain indispensable functions in cell growth, and that leads me to my next point.

The effect of all these experiments is to lead us first to the conclusion that in addition to the ten chemical elements acknowledged to be essential to the higher green plants, manganese, boron, zinc, and probably silicon, aluminum, and copper are to be regarded as essential; and second to the conclusion that it is not unlikely that further research will demonstrate that several other chemical elements are also essential. There is no longer a closed list of chemical elements essential to plant growth even though there may still remain some closed minds with respect to that important point. But when we have admitted all this the most important problem in this field still remains and that is what is the function of these elements in plant cells? Even the difficulties of providing adequate technique for arriving at the foregoing conclusions pale into insignificance compared with the difficulty of devising hypotheses, to say nothing of experimental technique necessary to the solution of this really fundamental problem connected with the physiology of the essential chemical elements. It is one thing to prove that zinc is essential to a plant's life; it is quite another and much more difficult thing to prove why zinc is essential to

that plant's life. Nevertheless, such is the confirmed optimism of him who seeks the truth, the scientist is far from hopeless of solving this fundamental problem too. It should be remembered, however, to appreciate how difficult this problem really is that even in the cases of the chemical elements long known to be essential to plants we are ignorant of the functions which they perform. While it may be a partial answer to this assertion to claim that we know how oxygen, hydrogen, nitrogen, carbon, sulphur and phosphorus function in plants because they help to make up its living tissue, it is an incomplete and unsatisfactory answer at best, and besides we haven't even an inkling of why the other elements in the original group are indispensable, certain guesses to the contrary notwithstanding.

We can none the less see some possibility of formulating hypotheses as bases for further experiments. I may perhaps be pardoned for suggesting some such hypotheses in the case of the newly discovered essential elements, inadequate and crude though they be, with the hope that they will stimulate others to make better hypotheses. It should be understood at the outset that there is little probability that any proposed hypothesis or suggested experimental procedure will have cogency in the case of every essential element. It is not to be expected that zinc plays the same rôle in cell metabolism which is played by boron for example. The same conception applies to the elements which are needed by plants in much larger quantities such as potassium and magnesium, and which I am leaving out of consideration in this closing part of my paper. Harking back to the introductory part of this paper the reader is reminded of the emphasis I have placed on the importance of the position and the kind of atom in the molecule as determining the latter's properties. Now if, for example, an atom of zinc is placed in a certain position in a molecule of some complex proteid or even some less complicated organic compound characteristic of the protoplasm it may yield a substance of certain properties without which certain organs of the cell can not function. In the absence of zinc such a substance could not be formed and the cell would cease functioning and die. While zinc is required by plants in very small quantities only such small quantities could easily be equal to the task of furnishing one or more molecules of zinc to enormous numbers of cells and thus provide the latter with all of that element which they require.

The foregoing hypothesis with respect to the manner in which zinc may function may perhaps also be applied to other elements needed in small quantities by plants, but not necessarily. However that may be I can see in it certain elements of validity when I recall the interesting mechanism of cell division and particularly the part played therein by the nucleus, its constituent chromosomes and their hypothetically constituent genes. Geneticists have produced strong, almost indisputable, evidence of the manner in which characters are carried in the genes of the chromosomes. Since, however, the genes carry certain definite units which in turn contain the elements of one or more traits of the organism to which they belong is it not possible that the nature of the traits thus borne by the genes is influenced by the chemical structure qualitative and quantitative of certain substances which they contain? If this is so and any chemical element necessary thereto is missing the whole structure must disintegrate. But if that happens the cells must die. There is some evidence published by Warington and by Warington and Brenchley which seems remotely to lend color to such a hypothesis inasmuch as they found that in the absence of boron the structure of meristematic tissues disintegrates and particularly in

the region of elongation immediately behind the meristematic cells.

It has occurred to me also, as it has occurred to others, that some of these newly discovered elements might be necessary to the normal functioning of one or more of the universally occurring, numerous, and diverse enzymes of plant cells. For this purpose we may use the term enzyme in a very general comprehensive sense to include the so-called catalysts. Much is known about how the enzyme catalase functions in relation to oxygen in living cells, and similarly much is known about the function of diastase in relation to starch and sugar and so forth through the long list of enzymes. But we know nothing of the constitution of these enzymes nor do we know much about the elemental chemical requirements which condition their useful functioning. The imagination readily suggests an indispensable place for such elements as boron in the functioning of some if not all of the enzymes upon the efficiency of which the cell's own integrity may rest. Moreover, we know that in purely inorganic systems certain chemical elements may speed up a chemical reaction enormously by their presence without becoming part of the products of the reaction. We call such substances catalysts and regard them popularly as inorganic enzymes. For example, it is well known that the oxidation of sulphur dioxide into sulphur trioxide may be markedly hastened by the presence of the element platinum in a certain fine state of division, but platinum is not a constituent of sulphur trioxide, the product of the reaction. And yet we know little of the mechanism by which platinum or similar catalysts hasten the reaction in which they are found to function. Is it not possible in view of the great complexity and mobility of the reactions in plant cells that such elements as zinc and copper may be responsible for making possible certain fundamental catalytic reactions in the synthesis of plant substance without which cells can not live or function?

I have suggested only a few of the many possible hypotheses and proposals which the imagination conjures up in meditating on the fascinating problem of the chemical elements essential to plant life. Whatever should prove to be the true explanation for this remarkable potency manifested by infinitesimally small quantities of some of the chemical elements in plant life, it is certain that the fact of the indispensable nature of some chemical elements hitherto considered as unessential constitutes one of the most striking evidences of the overwhelming importance which so frequently attaches to the infinitesimally small in our world. This can never cease to be a source of wonder and fascination to the reflective mind. Moreover, it teaches us, as we have been taught again and again in the past, that great apparent refinement of experimental procedure may always be subject to greater refinement and that that may in turn result in new and important discoveries.

ORIGIN OF OUR PRESENT MATHEMATICS

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MORE than half of the mathematics of to-day has been developed since the beginning of the nineteenth century. These developments include a considerable part, but less than half, of what is commonly known as elementary mathematics. To emphasize the modernness of some of our present elementary mathematics it may be noted here that the history of the simplest methods now known for constructing geometrically the roots of a quadratic equation, even when these roots are imaginary, extends into the year 1925. In a general way it may be said that the mathematics of to-day represents largely a survival of the simplest methods to prove certain desirable results. In other words, it exhibits mainly the most economical known methods to secure desired intellectual penetration. At any rate, this is what the mathematician thinks he sees in his work.

This general principle of the development of the mathematics of the present time exhibits clearly one of the greatest difficulties encountered by students of the history of our subject, since such a student usually deals largely with antiquated and unnecessarily difficult methods. It is obviously desirable that the heaps of discarded methods which have been left behind during the development of our subject should be reexamined from time to time to see whether in the light of later advances certain of these discards may be worth preserving, but the mathematical world can well afford to forget some of the mistakes of the past, and a history of our subject, which is largely based on fruitless work, is of questionable value as a history. It should, however, not be inferred that the mathematical historian necessarily deals largely with discarded methods and with fruitless efforts. One of the characteristics of mathematics is that some of our present methods were perfected very early and seem to be permanently useful.

The motives which led to the early development of mathematics are probably of greater interest to the average educated man than an accurate account of the nature of these developments. Hence it may be desirable to note here that Plato regarded the ignorance in his day with respect to solid geometry as laughable and disgraceful, and added that this ignorance would be more becoming to hogs than to human beings and that on account of this ignorance he was ashamed not only of himself but of all the Greeks. This sounds the keynote of the motives which led the ancient Greeks to make such remarkable progress in mathematics. They were interested mainly in securing intellectual insight and realized that such insight reflected great glory on their race as well as on the individuals who first secured it. Unquestionably, there were many other motives which contributed towards the early development of our subject. Some of these were utilitarian, but mathematics, like other sciences, seems to owe most of its progress to the desire to know the facts and the willingness to be guided by them.

In recent years a number of discoveries have been made as regards the mathematical attainments of the Maya of Central America and Southern Mexico. In particular, it has been noted that they employed a positional arithmetic with a symbol for zero, at least in so far as using it as a notational sym-

bol but not as a number. It is, however, unlikely that this development of mathematics had any influence whatsoever on the later advances along this line elsewhere. There is obviously a marked difference between the importance of such work and that of similar work done elsewhere which served as a stepping-stone for further progress. The latter is an essential element in the study of the origin of the mathematics of the present time, while the former is non-essential in such a study. This explains why it has been said that the work of the Chinese may be entirely neglected by those who study the development of our present mathematics. No single instance in which the work of the Chinese has affected this development is now definitely known to exist, notwithstanding the large amount of space devoted to the Chinese in some of the histories of our subject.

In studying the origin of our present mathematics it is therefore unnecessary to study all the known ancient mathematical systems, even if these systems may be of great interest in themselves. In fact, the literature relating to these various systems has grown so rapidly in recent years that it is almost impossible for one man to keep in close touch with all of it. The work of the student of the history of our subject is simplified by the fact that the ancient Greeks so greatly excelled other ancient peoples along mathematical lines that later generations were influenced mainly by their work and neglected sometimes for a long period of time even superior work of other nations along particular lines. For instance, the Arabs did not adopt some of the algebraic advances, including the use of negative numbers, made earlier by the Hindus, and hence the mathematics of the Hindus need not receive much attention on the part of those who desire to trace our present mathematics to its origin. It is becoming more and more clear that the mathematical developments of the Hindus and of the Chinese were largely influenced by those of the Greeks.

It has often been assumed that our present number symbols are due to the Hindus. This is so far from being established at present that a recent student of this question makes the following statement: "It may now be regarded as proved by Bubnov that our present numbers are derived from Greek sources through the so-called Boethian 'apices,' which are first found in late tenth century manuscripts. That they were not derived directly from the Arabic seems certain from the different shapes of some of the numerals, especially the 0, which stands for 5 in Arabic."[1] Hence those who desire to get as close to the origin of our common numerals as they can authentically at the present time do not need to study the various number symbols of ancient India for this purpose. The common term "Hindu-Arabic numerals" is therefore not strictly in accord with present authentic knowledge along this line.

Figuratively speaking, it may be said that the ancient Greeks constructed the earliest known mathematical ladders for the purpose of reaching the higher fruit on the mathematical tree. The earlier races picked only such fruit as they could reach from the ground. The advantages to be derived from the use of these ladders were recognized by all the later races which made serious mathematical progress, but for many centuries after these ladders were first constructed the mathematical appreciation of the world was slight and many of the mathematical advances, even some of those made by the Greeks themselves, were forgotten. In particular, what was achieved in Alexandria from the close of the third to the sixth century of our era has been practically lost except in so far as this work may possibly have influ-

[1] Robert Steele, "The Earliest Arithmetic in English," 1922, p. xvi.

enced the Hindus and the Arabs, and may thus reduce still more the credit now usually given these peoples for having made original mathematical advances.

Although the Greeks are preeminently the people of mathematical history to whom the adage "to him that hath shall be given" applies, it is probable that even they were the originators of considerable work for which others are now given credit. It is possible, in particular, that their algebra was developed considerably beyond what may be inferred from the part of the work of Diophantus, which has come down to us, and that they may have used explicitly the sine function in trigonometry at an earlier date than the Hindus. On the other hand, it seems well established that many valuable trigonometric tables were computed by Arabian scholars but did not become known in Europe until after similar tables had been computed and published by Europeans. The student of the history of our present mathematics may reasonably be less interested in what progress various nations may have made along mathematical lines than in the question of the effect, if any, that the work of these nations may have had on the development of our present mathematics.

A fundamental fact which is clearly illustrated by the development of our present mathematics is that while reading is a good thought stimulus it, like some other stimulants, constitutes by itself a pernicious intellectual diet. Mathematicians wisely recognized the superiority of the work done by the Greeks in comparison with work done by other ancient peoples along similar lines, and hence they properly studied the former work very carefully. For many centuries they failed, however, to lay sufficient stress on the great shortcomings of this work and the great barriers to further progress created by these shortcomings. Among these shortcomings the very limited number systems of the Greeks are most conspicuous to the modern student of elementary mathematics. One of the most harrowing experiences of the human race has probably always been the burden of debts, and one might think that some of the advantages of the use of negative numbers would have been so forcibly suggested thereby, as well as by many other experiences, as to lead to an early introduction and a wide use of these numbers.

This was, however, not the case. The ancient Greek number systems were signless. In this respect the Greeks seemed to have been unanimous while they were not as unanimous in saying that *one* is not a number, as is often assumed. Naturally most of the enthusiastic admirers of the ancient Greeks for many centuries adopted their mathematical faults as well as their mathematical virtues, and we find even in the eighteenth century European mathematicians of considerable note who contended that negative numbers should not be used on account of the logical difficulties which they present. In the seventeenth century, as noted a mathematician as Thomas Harriot thought he had proved that an algebraic equation could not have negative roots. It was not until about the beginning of the nineteenth century that the legitimacy of the use of negative numbers in mathematical operations was fully established, notwithstanding the fact that the great usefulness of these numbers in such subjects as trigonometry and analytic geometry had become apparent at a considerably earlier date.

The preceding reference to the introduction of negative numbers may serve to suggest the fundamental rôle of formalism in the development of the mathematics of to-day. It was not until after it was established that negative numbers obey the formal operational laws of algebra that these numbers were fully accepted. Steps towards the establishment

of this fact may be found in the work of various Greek writers. For instance, Euclid knew that $(a-b)^2=a^2-2ab+b^2$, although he did not express his result in this formal manner. The fact that the product of two subtracted numbers becomes an added number, provided the positive subtrahend exceeds the positive minuend, was not only clearly exhibited in the work of Diophantus but was explicitly expressed in this work. The slowness of the introduction of negative numbers under such formal influences as the close approaches to these numbers in widely known Greek works and their very apparent usefulness presents a clear illustration of the intellectual attitude during many centuries preceding the beginning of the nineteenth.

The great importance of formalism in the development of mathematics may be illustrated by the wide difference between the use of the equation in chemistry and in mathematics. In the former subject the equation serves to express in a clear way what is already known, while in the latter the algebraic equation of degree n involves not only the unknown which has been explicitly put into it but also $n-1$ others, and hence it serves to extend the field of research and becomes itself an object of study. Here again the ancient Greeks failed to make a very good beginning, since they were satisfied with one root of the quadratic equations which they considered. In fact, it was not until the seventeenth century that it was definitely assumed that every quadratic equation has at least one root and it took almost two centuries more to secure a clear insight into the nature of the numbers by means of which such equations can always be solved. If our modern students can now master such matters with very slight effort, as we usually assume they can, mathematicians have succeeded marvelously in their efforts to simplify matters, and the view expressed at the close of the first paragraph is at least partly justified.

SOME PHILOSOPHICAL ASPECTS OF RECENT ATOMIC THEORY

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THE problem of the constitution of matter goes back to remote antiquity for its inception. Through almost all the ages it has excited the keen interest of thoughtful men, and to-day its solution has become the principal goal of modern physical science. Beginning as a philosophical problem to be attacked by meditation solely, it is now being worked upon by the combined resources of both experimental and theoretical physics. Whether the philosophers, as a class, may be said to be still interested in it is doubtful. During the passage of the years their attention has been diverted to other problems, and the unraveling of the twisted, hidden thread of the structure of matter has become pre-eminently the task of science.

And yet when we consider that the early philosophers founded the atomic theory and that it is just this theory which forms the threshold of our modern attempts at a consistent theory of matter, it seems a pity that physical science and philosophy are so widely aloof in this interesting period of the development of knowledge. The rise of the atomic theory in physics and chemistry has been concomitant with a general shifting of major philosophical interest to other fields than ontology and epistemology, namely, to ethics, religion and more recently to psychology. It is doubtless this fact which has led most educated people (I mean educated laymen, not themselves scientists) to believe that the problem of atomic structure is solely one for science to concern itself with; and indeed one often hears the *vague speculations* of philosophy contrasted to the *solid* facts of physical science. What with the popularizers' glib and facile talk about protons and electrons, stationary states and quantum jumps the poor layman is apt to acquire the impression that modern atomistics has completely arrived! And I fear that some of us in the scientific fold are not a little responsible for this state of affairs. There is no doubt that the reality of the atom and its structure is fast becoming an article of holy faith among physicists generally in spite of the incomplete nature of our modern theories, an incompleteness which is but too manifest to those working most closely with the subject.

For this reason it seems to me to be time to re-emphasize the place of metaphysics in atomic theory, lest it be forgotten that there is an important philosophical element in all this development. It is a truism that no science can advance far without the aid of a metaphysical element. This bald statement may cause horror to many experimentalists, but by it I am merely emphasizing that the successful development of any science is absolutely dependent on the manufacture of hypotheses and that the state of progress to which the particular science has attained is due largely to the character of the postulates on which it has been built. Nowhere has this been more conspicuously evident than in the rise of atomic theory in the physical sense. It was the bold guesses of Prout and Dalton which gave so much stimulus to the advancement of chemical knowledge that they practically founded modern chemistry; while the revolution-

ary assumptions of Planck, Rutherford and Bohr are directly at the basis of the enormous mass of investigation into the constitution of matter which we have witnessed during the past two decades. It is true that physics, like all science, rests on experimentally determined facts, but it stagnates without the spur of hypothesis, of a theory to guide the seeking out of the facts and to accomplish the correlation of the new with the old. In its choice of what I choose to call a *metaphysics* (in the sense of something beyond the observed facts of physics) it finds its success or failure. By a successful physical theory we thus mean a postulate or group of postulates relatively simple and few in number involving quantities which may themselves not be observable or measurable and yielding on analysis relations which are consistently satisfied by the observed data over a wide range of physical phenomena. Naturally the greater the range of phenomena which can be consistently correlated with respect to the group of hypotheses, the more satisfactory the theory; likewise the greater the number of avenues of experimental research opened up by the hypotheses the more successful is the theory. A complete analysis of what constitutes a successful physical theory need not detain us here. Vivid sidelights on the many phases of this question are to be found in the work of Poincaré, which every student of physics should read and ponder. But what I am trying to emphasize here is the philosophical element that we should never forget.

Lord Kelvin spent a good part of his later life elaborating and working on the elastic solid theory of light. That work can not be considered without value, and yet we must recognize that his hypothesis has not been a fruitful one in the light of events, as judged by the standards just set forth. On the other hand, the electromagnetic theory, with all its difficulties, *has* been what we may call a success. The advance of physics is full of like examples, and they all indicate the extreme importance of the choice of hypotheses.

In this connection there often arises an interesting psychological difficulty. It is this: having once chosen a hypothesis or group of them on which to base the development of a physical theory like that of atomic structure one may, often almost imperceptibly, fall into the state of looking upon the system chosen as the only true reality. It is then that the discovery of some new phenomenon not easily explainable in terms of the original hypothesis injects temporary confusion into the science. Of this there are numerous illustrations in the development of physics. One commonly cited nowadays concerns the difficulties over matter in motion which arose from the use of the older metaphysics of absolute space and absolute time. From the standpoint of the present article, however, a still more illuminating example is to be found in the woeful mix-up in our present ideas on the emission and propagation of radiant energy, a problem very closely bound up with that of atomic structure. The researches of the last century based on the hypothesis of the undulatory nature of light were so successful and led to the creation of such a well-established, consistent body of knowledge that it was hard to doubt the reality of it all—this was gradually taken for granted, I think, by most physicists. It was for this reason that the discovery of the discontinuous nature of the emission of light has proved so disconcerting; for we are here dealing with phenomena which in no simple way have been subsumed under the wave theory, in spite of the many attempts that have been made to do so. The warning provided by this example is very plain: we must never be too ready to attribute complete reality to any one hypothesis no matter how satisfactorily it may appear to correlate known facts.

There is always the chance that it may break down in a crucial experiment.

We must grant, of course, that it is the ultimate aim of physics to unify all our knowledge of the physical world in as small a number of generalizations as possible. Yet it is a moot question as to how much is gained by trying to force new facts to fit an old hypothesis. The comparative experience of the late nineteenth and early twentieth centuries would indicate that the physicist who is unwilling to consider entirely new and in themselves not completely understandable concepts will not get very far. Patching postulates may allow us to correlate a large amount of data, but in the long run it violates the well-known criterion of Mach, as well as the famous razor of William of Occam. The point I am trying to lead up to is just this: that there are often occasions when it is not only necessary but desirable to tolerate a *dual* representation of phenomena. This is exactly what we now have in the theory of radiation. As long as we are talking about the *propagation* of light the wave hypothesis is an extremely satisfactory one. On the other hand, the quantum theory, the fundamental concept of which is so difficult for our minds to absorb since it breaks so completely with previous notions, accounts with comparative ease for all hitherto discovered phenomena connected with the *emission* of light. This constitutes a dual representation and is apparently causing many physicists much sorrow and dissatisfaction. It is also possible that knowledge of this situation has led many laymen to feel that modern physics is after all only mental ping-pong. This is unfortunate, for the dual nature of our modern view of light is nothing to be ashamed of. On the contrary it is proving a wonderful stimulus to research.

Moreover, looking at the matter of the dual representation in a somewhat different light, I think there is a sense in which we may be justified in considering both concepts, *i.e.*, waves and quanta, mutually consistent. I mean that it is perfectly possible to conceive of the emission of radiant energy in quanta from the individual atoms with the consequent production of waves before the quanta get away from the atoms. That is, in the medium in which the atoms are embedded, we have to think of radiant energy as always in the form of waves, while in the atoms it must always be thought of in terms of quanta. This of course introduces an element of discontinuity, but there should be nothing alarming about that. The very assumption of the existence of the atom itself with its component parts has already brought in discontinuity, and we may very well expect that the concept of discontinuity is to be one of the most fundamental in modern physics. At any rate it is already predominant in the minds of most of us.

In coming to the main problem of the structure of the atom itself, it is not improbable that we have to deal with a dualism closely connected with that involved in light quanta and waves. By that I mean that even if we are willing to accept the picture of an atom as composed of nucleus and electrons there is no *a priori* reason to suppose that these particles behave when together in the atom as they behave as individuals at considerable relative distance from that atom and other atoms, *i.e.*, in what we may call free space. As a matter of fact we know that the "free" electrons in their motion obey the laws of classical mechanics as modified by relativity, while it has so far been impossible to represent the motion of the electrons in the atom (the "bound" electrons) by any consistent application of classical laws. In view of this it has been suggested that the phrases "position of an electron" and "velocity of an electron" have entirely different meaning when applied to the bound electron than they have for

the free electron. *This view is inherent in the theory of Heisenberg, the so-called new quantum mechanics. It involves a* dual representation which here again seems to be meeting with success. Even on the older Bohr theory we have dualism with the postulation of the discrete stationary states, only here there was a concession to our traditional mechanical concepts in the assumption of motion of the electrons in actual orbits determined by the laws of classical dynamics. For the simple case of hydrogen (one electron) and hydrogen-like atoms this theory has worked very well, but already in the helium atom with two electrons the problem has not yielded results at all in accord with the observed data. The conclusion is patent that the dualism of the early Bohr theory was not sufficiently thoroughgoing. The newer theory discards electron orbits and focuses attention on the atom as a whole which can exist only in certain discrete stationary states. The atom is then represented as an aggregate of virtual linear oscillators with frequencies corresponding to all possible transitions of the atom from one stationary state to another. Such an aggregate is of course a doubly infinite matrix and hence the name "matrix mechanics" which has been applied to Heisenberg's theory.

This theory has many interesting philosophical aspects. For the moment let us consider a suggestive question which has arisen in connection with the development of the new mechanics. We may phrase it in this way: Is it after all really possible to build a completely consistent theory of atomic structure in terms of our ordinary conceptions of space and time? To give a precise answer to this question would demand a more detailed analysis than I wish to enter upon here, but there are a few points which are worth mentioning. If by the kind of theory stated in the question we mean one in which we are allowed to use freely the classical electrodynamic concepts of position, orbit, velocity and acceleration, then the *weight of the evidence so far is definitely* negative. As has already been emphasized above, it would have been very remarkable and almost too good if concepts in terms of which we can successfully describe the motions and behavior of free electrons and α-particles were found capable of dealing with these same particles when close together in the atom. On the other hand, we must consider the possibility of extending the meaning of the terms so that the phrase "position of an electron" inside the atom has a definite significance closely related to that attached to it on our usual conceptions, and similarly for the others. No one would be willing to deny that a *consistent* theory could be erected on such concepts, and it might work. For example, it may very well be meaningless to say that at a certain definite instant of time an electron is at a certain point with reference to the nucleus and the other electrons in the atom. It may prove more desirable, if we are to speak of the distribution of electrons in the atom at all, to say that by position of an electron we mean simply an average space distribution of negative electricity about the nucleus. As a matter of fact it has been by an assumption of this nature that the Bohr theory has been able to account in *approximate* fashion for the structure of atoms with several electrons. Of course one may say that this amounts practically to discarding entirely the concept of electron position and this is true if we interpret the word "position" in its ordinary sense.

This in turn suggests the interesting consideration: Even if we find it necessary in order to build a consistent successful theory to introduce concepts which differ from our usual ones, will it or will it not be desirable to translate the results into the old terminology and talk, for example, of electrons revolving

in orbits, etc.? That is, will we ever be willing to abandon utterly the atomic model in terms of electrons and nucleus? If we follow the tendency set by the newer theories we must certainly do so. For it is one of the principal postulates of the matrix mechanics that the theory should concern itself simply with the *measured* quantities in the atom, namely, the frequency of the emitted radiation, its intensity and polarization, and the energy radiated. Carried to its logical conclusion it forbids us to have anything to say about electrons at all. But I venture to believe that most modern physicists are not going to remain greatly satisfied with a theory of that kind, no matter how consistent or even successful it may be. They will doubtless insist on translating the results into the terminology of a mechanical model. This is due to the unescapable psychological bias which makes us say that we can "understand" a theory in which an actually conceived particle like an electron moves in a definite way and so gives rise to other phenomena. And so it appears likely that the atomic model will still flourish as long as the "old familiar notions" still hold sway. It is another question and somewhat out of our province here whether we shall in time become sufficiently familiar with the purely quantum concepts of energy and frequency in themselves alone, to be willing to forego the space and time scaffolding into which we now must place them. It might be remarked on this point that there has been in fact a gradual growth of familiarity on the part of physicists with concepts which began by being extremely recondite. The notion of the electromagnetic field is an illustration.

It is probably rather early to discuss from a philosophical viewpoint the still more recent theory of Schrödinger in which the motion of the electron is replaced by that of a wave, which, however, is not the radiant energy wave but only a phase wave with a frequency proportional to the energy of the atom. Here we are again getting away from the pictorial viewpoint in the replacement of a discrete particle moving in a definite orbit by the distribution and propagation of a certain undefined function throughout space. As a mathematical formalism the theory has proved itself of great value in the handling of many atomic problems, but for the reasons amply outlined above, it is unlikely that the descriptive content which Schrödinger has tried to put into it will appeal to many physicists, who once again will seek to translate its results into the familiar picture.

It must be remembered, and this is an extremely important point, that in no one of the more recent theories is there any attempt seriously to account for the fundamental quantum relation, $E'' - E' = h\nu$; that is, that when the atom changes from one stationary state with energy E'' to another stationary state with smaller energy E', there is radiation emitted of frequency $\nu = \frac{E'' - E'}{h}$, wherein h is Planck's constant. It is allowable to believe that the whole mystery of atomic structure lies in this simple formula, and our attitude toward the whole problem is more or less clarified by the attitude we take toward this relation. There are two courses to pursue. We can first look upon the relation as really fundamental in the sense that it is inexplicable in terms of anything else. It simply expresses the quantum concept which seems necessary for the description of all small scale processes in which single atoms are concerned. From a philosophical point of view it is, of course, natural to expect that a law governing the behavior of a discontinuous entity like the atom should be expressed in the form of a *difference equation* rather than in the form of a *differential equation*. But as to the exact nature of this difference equation we

know *a priori* absolutely nothing. And the actual equation which we are forced to use has no meaning in classical electrodynamics if we give to energy and frequency their usual significance. This offers an outlook on our second course. It is conceivable that by associating *new* meaning with the old concepts or at any rate subjecting them to new conditions we may make the classical relationship take the quantum form. For example, we ordinarily think of the frequency of any periodic wave propagation as a *constant* quantity dependent only on the source of the disturbance and independent of the medium. Now it might be that this is not true of the state of affairs inside the atom. Thus there might be a progressive change in frequency inside the atom, such that in a transition from one state to another, although the electrons or whatever entities do jump may make oscillations of varying mechanical frequency, these frequencies would all be changed into one radiation frequency before the radiation left the atom.

It is evident that there is a great deal of room for ingenuity in making artifices to fit the quantum transition equation into our classical ideas. These hypotheses will have to be judged by their fruits and at present no one of them seems to be of sufficient value to be pursued very far. The relation under consideration has appeared in so many phases of atomic phenomena and has been instrumental in bringing so much order into what would otherwise be wholly chaotic material that we surely can not discard it altogether. And in retaining it, it is probably better for the present to view it as a fundamental postulate on which to build any theory of atomic behavior which seems best able to fit the facts.

This is not the place to consider in too great detail the problem of what takes place inside the atom, but it may be worth while to reiterate that in the broad sense the attack on the problem may be made from two philosophically quite different points of view. If we adopt the first we seek to create a *picture* involving conceivable motions of some entity or entities in space and time. These entities need not be electrons or particles of any kind. For example, they might include continuous material media which could move subject to certain boundary conditions. In this connection it may be worth while to recall the fact that as far back as 1903 Ritz succeeded in devising a two-dimensional bounded continuum whose oscillations have natural frequencies obeying the Balmer law. It might be possible to attach a physical significance to the particular continuum chosen; the only drawback to it being its extremely complicated nature. Simplicity must be considered one of the essential features of any successful picture and it is for this reason that the Bohr theory has proved so alluring, yet its very simplicity has involved it in such serious difficulties that no one doubts that it must be materially modified. This modification may still retain the "picture" point of view, or it may, as in the matrix mechanics or in the more recent wave mechanics, discard completely the attempt to make a picture of atomic processes and content itself merely with the formulation of certain mathematical relations which yield the proper values for the measured quantities. It may be well, however, to re-emphasize here the doubt (already expressed above) that this method of attack will ever satisfy physicists in general.

From what has been said it will be clear, I think, that the modern atomic physicist is becoming more and more of a philosopher. This does not mean that he is losing touch with facts, but rather that he is coming more and more to realize that the data of atomic physics are so extremely complicated that without philosophical interpretation, *i.e.*, the

introduction of new and satisfactory hypotheses, they are meaningless. And we have seen that the choice of hypothesis, that is, the character of the physicist's philosophy, determines to a large extent his success in interpreting the facts at his disposal. This attitude on the part of the physicist, which after all is not new but is only becoming more and more emphasized, is bound to have some influence on the development of philosophic thought in general.

Thoughtful physicists have for a long time affirmed quite strongly that the question of the reality of the external world has no meaning for them. For they have conceived their task to be solely the analysis of a certain group of our sense impressions; behind these they have not desired to go. Yet with the increasing complication of modern physics, particularly in the atomic realm, there has arisen this peculiar and somewhat paradoxical situation: having *created* the atom and its constituent parts to account for a vast mass of indubitably valid phenomena, physicists are coming to believe in the intrinsic *reality* of their creation. That is, it is real to them in the sense that when they hear of any new phenomenon, the chances are that after pondering they will remark, "Oh yes, that is because the protons and electrons go so and so!" It is just as hard to convince the physicist who has performed experiments in radioactivity, X-rays or cathode rays of the unreality of electrons as it is to convince the average person of the unreality of the stone on which he stubs his toe. The physicist, therefore, unconsciously perhaps but nevertheless quite inevitably takes up a rather definite view as to the nature of the external world, in his insistence that the protons and electrons of the atom are its building stones and primordial elements. We must not blame him for this, for it is a thing he can not help. Yet what it means is this: that the ideal—the creation of the mind—is in this case for all practical purposes identical with the real. In modern physics the strongly contrasted philosophical doctrines of realism and idealism merge into a common pragmatism. We build a hypothesis which seems best to satisfy our longings for logical completeness and then we act toward our hypothesis as if it were reality, because it works. This is a very sensible attitude, yet, as has been pointed out earlier in this article, we must never forget that this reality is of necessity a transient one. New facts render old hypotheses untenable—the old reality yields to new reality and so science progresses. More and more it becomes clear that the true reality is but the ideal with which we have become so familiar as to believe in it and have faith in it.

There may be a question as to the influence on the development of philosophic thought itself of such considerations as we have presented above. But it seems to me that as far as ontology and epistemology are concerned, more philosophers are realizing that the way to progress lies in a greater attention to the data of science. After all in that direction lies our only *sure* prospect of knowledge. Certainly it seems that a searching examination of the concepts which lie at the foundations of scientific theories would provide more useful problems for philosophical attack than the construction of philosophic systems which have little connection with the data of our sense perceptions. That this is already being realized is clear from an examination of the works of Russell, Whitehead and others. It is to be hoped that this movement will continue with increasing vigor. For if the philosophers do not press forward in this direction the scientists and particularly the physicists must.

PHARAOH'S DOCTOR

By ANTHONY J. LORENZ

THE line between the medical quack and the scientific surgeon was clearly marked at the very dawn of man's intelligence.

When primitive man had an attack of indigestion he blamed it on a host of demons.

When his skull was bruised in combat and he suffered a headache, he was more practical. He was able to understand the relation between his enemy's club and his physical hurt. He recognized the outside force causing his head to ache, but was unable to diagnose his internal ailment.

This is clearly shown in the publication of the first English translation of the Edwin Smith "Medical Papyrus"—the oldest scientific book in the world. The translation has just been completed by Professor James Henry Breasted, of the Oriental Institute of the University of Chicago, and is being printed for the New York Historical Society, the owner of the manuscript, by the Oxford University Press, which at present has the only facilities for setting up the ancient hieroglyphs in type.

This document, says Professor Breasted, is of unique interest not only to the Egyptologist and anthropologist in showing the awakening of man's reasoning powers regarding disease but of extreme importance to the history of medicine. The Edwin Smith Papyrus, a roll some fifteen feet in length, dates from the late seventeenth century B. C. and is regarded as the most important document in the history of all science surviving from the pre-Greek age of mankind. Its seventeen columns contain a portion of an ancient treatise on surgery and external medicine which began its discussion at the top of the head and, passing downward, presumably continued to the soles of the feet.

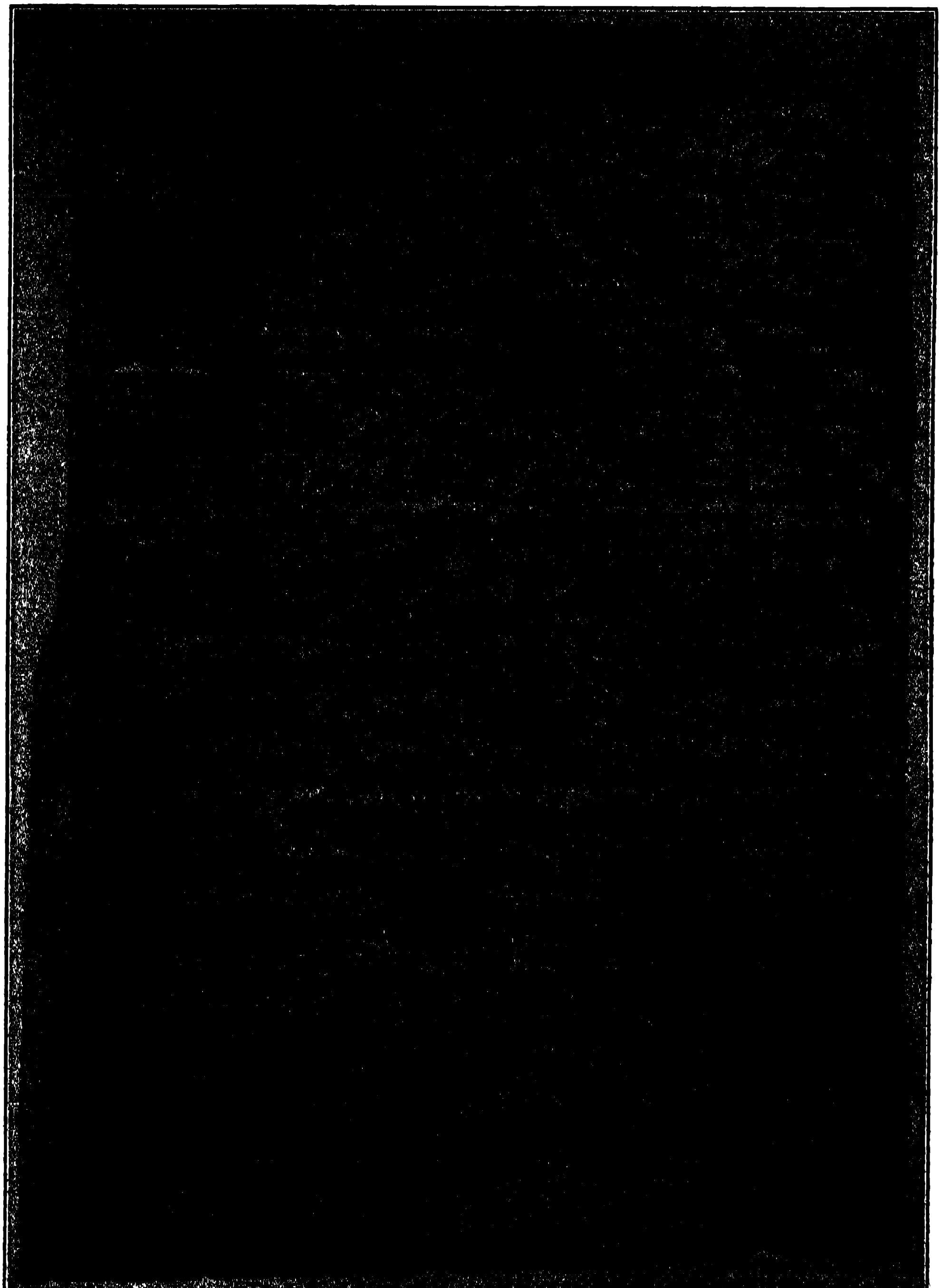
Unfortunately, the ancient scribe failed to copy further down than the thorax and the beginning of the spine the surgeon's observations of human hurts. The papyrus, however, contains so much information regarding the really remarkable knowledge which the author-surgeon of 4,000 years ago had that some of his diagnoses and treatment methods when shorn of their curious phraseology are surprisingly modern.

He had quite a complete knowledge of the human anatomy far in advance of medical scholars even of the middle ages; he felt that the heart and brain played important rôles in our physical make-up; he knew something of the pulse or pulsation and of the circulatory system.

In its text and glosses the human brain appears for the first time in medical literature. Its author knew that the folds of the brain lie in convolutions. His description of them is perhaps even more graphic than a modern physician might employ. He says they are "like those corrugations which form on molten copper" and in taking up this vivid comparison in a gloss he explains that the reference is to the floating slag forming on molten copper which the coppersmith rejects before he pours the metal into the mould.

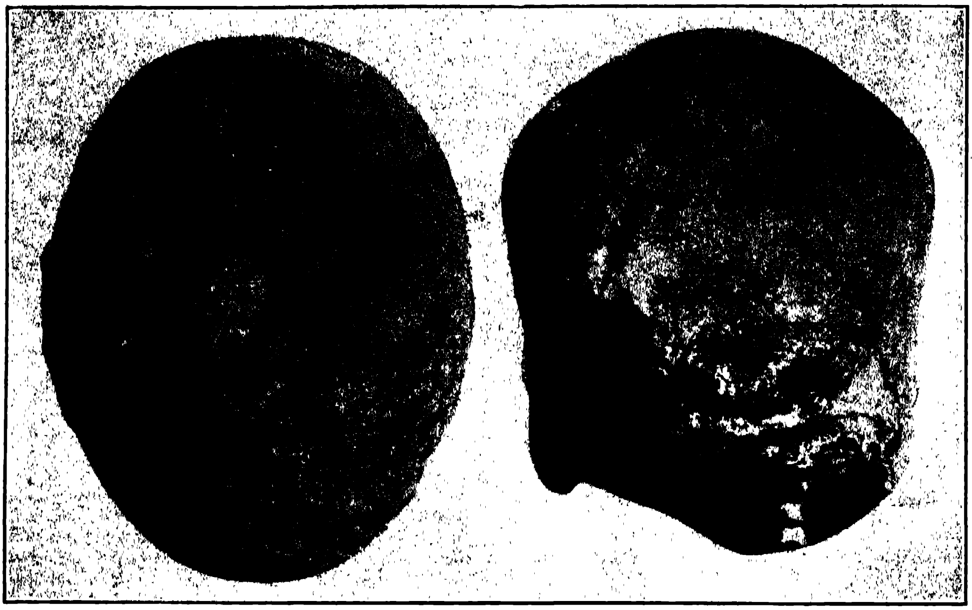
"Any one who has observed these convolutions into which the metallic slag forms itself will recognize the aptness of the ancient comparison," says Professor Breasted in his commentaries on the text.

In still another gloss is explained



A PAGE OF THE EDWIN SMITH PAPYRUS

THE OLDEST MEDICAL BOOK IN THE WORLD, DATING BACK TO THE SEVENTEENTH CENTURY B. C.



EGYPTIAN SKULLS

(LEFT) SHOWING SWORD CUTS WHICH MUST HAVE PROVED IMMEDIATELY FATAL AND WHICH THE ANCIENT EGYPTIAN SURGEON, AUTHOR OF THE SMITH PAPYRUS, WOULD HAVE DISMISSED WITH HIS "VERDICT NO. 3—A CASE I WILL NOT TREAT."

(RIGHT) THOUGH ITS OWNER SUFFERED A SEVERE SWORD CUT, THE SKULL DISCLOSES EVIDENCES TO THE MEDICAL EXAMINER OF HAVING BEEN TREATED ALONG THE SURGICAL LINES LAID DOWN BY THE AUTHOR OF THE SMITH PAPYRUS. THE PATIENT SURVIVED, ACCORDING TO G. ELLIOT SMITH AND F. WOOD JONES, BRITISH ARCHEOLOGISTS, WHO STUDIED THE EFFECTS OF ANCIENT SURGICAL PRACTICES ON HUNDREDS OF MUMMIES.

that "when rending open the brain" in a compound comminuted fracture of the skull "the membrane or skin enveloping the brain which is rent breaks open his fluid in the interior of his head."

This, said Professor Breasted, is the earliest known reference in medical history to the meningeal membrane.

Again, this old papyrus makes the earliest observation showing that the brain is the center of nervous control. The Egyptian surgeon in his practice had noticed that injuries to the skull and brain result in disturbing the normal control of various parts of the body, even as far away as the feet.

The most remarkable observation in his text-book is made in connection with still another case of compound, comminuted fracture of the skull which, however, displays no visible external contusion. Here the surgeon makes the following notes in his picturesque, though strictly scientific, observations:

> His eye is askew because of it, on the side of him having that injury which is in his skull; he walks shuffling with his sole, on the side of him having that injury which is in his skull.

To Professor Breasted the repetition of the word "that injury" suggests that the surgeon is calling attention to the fact of the fact of the effects of an injury in a situation which may be distant from the place of the observed effect.

"Much more remarkable," says Professor Breasted, "is the repetition of the detail 'on the side of him having that

injury which is in his skull,' " showing that the surgeon was aware of the relationship between the side of the brain which has suffered and the side of the body which is affected by the brain injury. The fact that he distinctly specifies in both cases on which side the affected foot and eye are with reference to the injured side of the brain is highly significant, and indicates that he has already discerned the localization of control in the brain.

On the other hand, there is no effort on the part of the ancient writer to correlate these evidences of a nervous system centering in the brain with similar defects arising from injuries of the vertebrae, and he does not attempt to discuss the loss of speech ensuing from the crushing of the cervicle vertebrae case examination.

Professor Breasted adds:

> Indeed, the Edwin Smith Papyrus discloses no word for "nerves" and there is no indication in any of the Egyptian documents that such a designation existed at this remote stage of scientific knowledge of the human body.
>
> The papyrus reveals to us an ancient Egyptian surgeon in contrast with the physician; with the ability to observe, draw conclusions and thus, within the limitations of his age, to maintain a scientific attitude of mind.

Whereas the physician of that day dealt with the majority of human ills as being of a demoniac origin and sought treatment for them in incantations and other magical formulas, the surgeon went about his work scientifically, the papyrus reveals. It differs strikingly from all the other known Egyptian medical books, such as the Papyrus Ebers and the Papyrus Hearst, in that it is not a list of recipes but an orderly arrangement of cases.

Systematically arranged, the material reveals an attitude approaching that of a modern-day scientist. Its cases are very largely injuries, such as sword cuts in the skull, bone fractures and contusions, resulting probably from injuries suffered in erection of those great monuments which gave Egypt the first place in architecture.

As these are due to physical causes quite clear to the surgeon-physician, they obviously had no connection for him with the activities of malignant demons of disease. Injuries, therefore, caused by intelligible physical agencies formed a realm not readily invaded by magical powers—a realm, as Dr. Breasted remarks, "in which the Egyptian physician gathered the observable facts of anatomy, physiology, surgery and therapeutics quite unbiased by his inherited tradition regarding the demoniacal causes of disease, and we have the mind of the ancient Egyptian revealed to us here as interested in the observable facts of science for their own sake."

The ancient author was a frank though cautious doctor with a seemingly high regard for medical ethics, who divided his diagnosis into three groups according to the seriousness of the ailment or injuries he might be asked to treat. He naïvely grouped them as follows:

> 1—An ailment which I will treat.
> 2—An ailment I will contend with.
> 3—An ailment not to be treated.

In sixteen out of the fifty-six physical examinations listed in the papyrus, the surgeon omits all suggestion of treatment. In twelve of the sixteen instances the unfavorable verdict number three is appended.

The author of the papyrus in his arrangement of cases evidently intended to pass from the trifling to the more serious or fatal cases. He begins with slight superficial injuries involving only the overlying soft tissues and then proceeds gradually to more serious injuries affecting the underlying bone.

Thus in the first section of the treatise is the case of a superficial scalp wound. Case number two is a more gaping cut

but, like number one, leaves the bone uninjured. Case number three, however, begins a series of deeper wounds affecting the skull. Case number four a compound fracture of the skull, number five a compound comminuted fracture. Case number six is the same as number five with the addition of a rupture of the meningeal membranes. Cases number seven, eight and nine are similar but fatal injuries to the skull.

Mechanical appliances and processes, on which the ancient surgeon relied, appear for the first time in the literature of medicine in the Smith Papyrus. Among them are lint made from a vegetable tissue and frequently applied both as a vehicle for the medicaments externally used, and as an absorbent of blood secretions. Plugs or swabs of linen, usually in pairs, and bandages made of linen and manufactured for surgical use by embalmers are listed and named as "coverings for physicians' uses." Medicaments applied externally were almost always bandaged on.

Adhesive plaster made of strips of linen, always in pairs, applied transversely "to the two lips of the gaping wound to cause that one join to the other" are called "2'wy of linen." Several references are made to surgical stitching.

"Thou shouldst draw together for him the gash with stitching," one of the passages reads. The word used to designate "stitching," or the verb "to stitch," is "ydr," in contrast to the term for adhesive plaster and stitching, "ndry," meaning "to draw together."

Cauterization is suggested in only one case, in the treatment of an unidentified tumor on the breast, and the instrument employed is called "a fire stick," probably the fire drill used by the Egyptians for kindling fires.

Three different kinds of splints were known to the old surgeon, according to the papyrus.

One defined as a "brace of wood padded with linen," is called a "md't of wood," for insertion in the mouth of a patient suffering with constriction of the ligaments controlling the mandible, and according to Dr. Breasted, suggests tetanus or lock-jaw. The surgeon ordered it applied to hold the mouth open and permit feeding with liquid food.

A second kind of splint was ordered for application to two fractures of the humerus and from the description may have been the forerunner of the modern surgical cast.

A stiff roll of linen was ordered as a third kind of splint in the treatment of a fractured nose.

Supports for maintaining a patient upright in bed are prescribed, and from the word used in describing them it would seem that they were made of adobe or sun-dried brick, probably made to fit the body of the patient.

The effective methods of the Egyptian surgeon in the use of such splints is also shown by Dr. G. Elliot Smith's examinations of more than a hundred fractures of the forearm in mummies among which he found only one that had failed to unite.

"In spite of the fact that a certain proportion of the cases of fracture (always due to direct violence) must have been compound," Dr. Smith remarks, that "only one shows any sign of suppuration having occurred."

The surgeon was evidently at a loss regarding the immediate mechanical manipulation of a serious fracture of the skull, but he recognized the importance of quiet, combined with a sitting posture maintained by the adobe piers, of normal diet, but with no binding of the injury and no medicine.

It would seem from the discussion of the case in the papyrus that no direct manipulation of the wound was attempted, and Dr. Smith in his mummy examinations declared that none of the

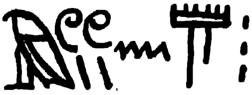
Fig. 1.  "two" ʾ-wy of linen

Fig. 2.  ydr (adhesive tape.)

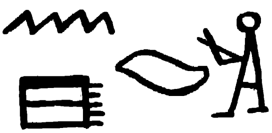
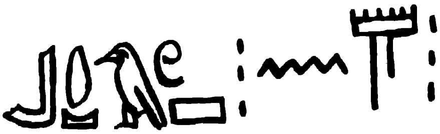
Fig. 3.  ndry (to draw together)

Fig. 4.  mdʾ-t (splints padded with linen)

surviving bodies "shows any indication that the process of trepanning was practiced by ancient Egyptian surgeons."

"It is an interesting fact," Dr. Breasted remarks, "that in our ancient treatise there is a sharp distinction between such mechanical and surgical manipulations and the treatment with medicaments."

In nearly all cases of injury the surgeon is charged to probe the wound, a process carried out with the fingers in most instances and in some instances "with a swab of linen." Attention is called to the pain which this probing produces: "both his eyebrows are drawn and his face is as if he wept."

A detailed treatment for a dislocated jaw bone, or rather its examination, is given in one instance:

"Thou shouldst put thy thumb upon the ends of the rami of the mandible in the inside of his mouth, and thy two claws (two groups of four fingers) under his chin and thou shouldst cause them to fall back so they rest in their places."

Thus the ancient Egyptian practitioner was inclined to include some things in the examination which a modern surgeon would readily classify as treatment. On the other hand, he includes in the proper treatment the use or application of medicaments and recipes, the characteristic agencies of the physician. He, therefore, placed the operation in the great majority of cases in the examination and reserved for his treatment the use of alleviatory and curative external medicaments, the recipes for which are so abundantly found in all the other medical documents in old Egypt. Here is the sharp distinction between the surgeon, on one hand, and the physician on the other.

In the treatment of a compound comminuted fracture of the frontal bone the surgeon-author has culled the only

magical treatment in his book of surgery and external medicine.

"It is a well known fact," remarks Professor Breasted, "that even in the mind of a modern man otherwise rational and scientific there may be found lurking surprising manifestations of superstitions. Undoubtedly, our surgeon never more than partially escaped the current superstitions of his age, even those which ran counter to his general attitude toward his craft or as in the treatment of the above case, to the rational views which he usually held."

In the therapeutic measures which the surgeon combined with his purely surgical procedures he is for the most part in an archaic age, suggesting so pointedly that his surgery is far in advance of his medicine.

In all the treatable cases he follows up his surgery with medicaments, although they are for the most part primitive in character. His favorite remedy, for instance, was fresh raw meat bound on to the wound on the first day, but no longer, and usually followed by a daily application of lint saturated with oil and honey. One of his remedies has thus far remained a mystery. It was the imru (ymrw) which, mixed with honey, he applied in cases of great soreness of the tissues. Imru is believed to have been a mineral.

While the general content of his materia medica would not commend itself to modern surgery it is of interest to know that in the case of an infected necrotic wound in the breast he prescribed the earliest known external application of salicin in the form of a decoction of willow (salix) leaves. Probably his ancestors were taught by experience centuries earlier the antiseptic effect of its use.

Another application he used for allaying inflammation contained dung, and was probably ammoniacal. His astringent application in this case, after he had reduced the inflammation, was a solution containing copper and sodium salts.

In two cases at least he made a more extensive use of his pharmacopoeia. In case forty-one, an infected wound in the breast, this old surgeon prescribed a cooling application consisting of a decoction of willow bark; an astringent application of a solution containing copper and sodium salts as well as poultices of unidentified herbs. In the case of a prominent abscess in the breast he prescribes "two cooling applications, the second containing mason's mortar; a solution for allaying inflammation made of sycamore leaves, acacia leaves and ox-dung; an astringent solution containing copper and sodium salts and a poultice of herbs."

The surgical student, for whom this book seems to have been compiled, was instructed carefully to watch for signs of paralysis:

"Instructions in regard to treatment of the perforation of the temporal bone: If thou findest that man to be silent, and he does not speak, thou shouldst soften his head with grease, pour (an unidentified medicament) into his ears: He may put his hands to his eyes but not realize that he is doing it."

A test for paralysis often repeated in the text is:

"Tell thy patient to look over his right and over his left shoulder and at his breast, if he is able to do so."

In fact, one is led to believe that this manuscript may have been a text-book in that first college of medicine in the history of the world—The Hall of the House of Life, which King Darius I of Persia had Uzahor-resenet restore.

In the sixth century B. C. under the patronage of Darius, whom Professor Breasted characterizes as "the greatest and most enlightened administrator of the early world before the rise of the Romans," was Uzahor-resenet, an Egyptian ecclesiastic, a high priest of the Goddess Neith at her temple in the

Delta city of Sais. This priestly aristocrat's statue, now in the Vatican at Rome, carried an inscription which says:

His Majesty King Darius commanded me to come to Egypt while His Majesty was in Elam as Great King of every country and Chief Prince of Egypt, in order to establish the Hall of the House of Life.

I did as His Majesty had commanded me. I equipped them with all their students from among sons of men of consequence, no sons of the poor were among them. I placed them under the hand of every wise man for all their work—I equipped them with all their needs, with all their instruments, which were in the writing, according to what was in them aforetime.

His Majesty did this because he knew the value of this art in order to save the life of every one having sickness.

Professor Breasted believes that the term "Hall of the House of Life" was an old one applied to archive chambers, libraries and the like, and probably refers to such a place rather than to a hospital. He adds:

In this remarkable inscription (on Uzahorresenet's statue) we find the earliest known mention of a medical school as a royal foundation. It is important to note that this Egyptian medical school at Sais was not being founded for the first time, but was being restored as the surviving old writings in Uzahorresenet's hands showed him it had been "aforetime."

We note with interest that the medical students of the sixth century B. C. in Egypt were selected from families of good social station, and that, as the last lines show, these young physicians were evidently also priests in the temple of the Goddess. Indeed the High Priest himself, Uzahor-resenet, bore the title "Chief Physician." Among the branches of instruction the reference to "instruments" shows us that surgery was included.

Among these highly civilized cities of the Nile Delta, the first large cities the Greeks had ever seen, the Macedonian kings of Egypt set up their enlightened scientific foundations at Alexandria. We see now that in medicine at least Darius had anticipated them. The important point to note is the fact that the support of old Egyptian medical instruction was continued by the Persians after their conquest of Egypt (525 B. C.). When, two centuries later, the Alexandrian physicians began to enjoy the princely support of the Ptolemies, they found themselves among the surviving native Egyptian medical schools and medical libraries of the Delta, when such contacts and influences as we have suggested could hardly have been escaped.

The ancient history of the Smith Papyrus as a whole, says Professor Breasted, illustrates the hazards which beset such records and their meager prospects of survival.

"It is now, without doubt," he adds, "thousands of years since the original copies of this surgical treatise, as penned by the hand of the nameless author himself, probably nearly 5,000 years ago, has disappeared or been destroyed. A copy survived the fall of the old kingdom 3000–2500 B. C. and its successive copies survived the fall of the middle kingdom, in the early eighteenth century B. C. and the advent of the Hyksos."

Professor Breasted believes that it was at this time, when upper Egypt was striving to throw off the foreign yoke of the Hyksos, a Theban scribe copied the ancient treatise on surgery which in content was then probably over a thousand years old.

Professor Breasted writes in his introduction to the translation:

It was as if a man to-day sat down to copy a manuscript written in the reign of Charlemagne, full of old words and archaic terms of speech.

The scribe was master of a stately and beautiful book hand, but he was totally ignorant of medicine, and when confronted with some highly specialized picture-sign, like that of the hewn mandible, he completely lost his ready command of his graceful and running form and awkwardly smeared together a blotted and angular picture.

He was excessively inaccurate, but occasionally noticed and corrected his errors—in one case placing an omitted word in the margin and calling attention to it by a cross, the earliest known asterisk in the history of book-making. He may have been an employe on the staff of some ancient copyist's office. In any case when he had copied the old treatise on surgery from

the beginning (the human head) down to the thorax and the spine he stopped in the middle of a case, in the middle of a line, in the middle of a sentence, and leaving the end of the long roll bare of all writing for some space, he turned it over and copied on the unwritten back a series of incantations against pestilence, to which he added three recipes, one for female troubles and two for improving the complexion. It is possible that the first purchaser, some local Theban practitioner who saw the unfinished treatise on surgery, ordered the scribe to stop and to copy for him this unsavory magical hodge-podge on the back.

Eventually this unknown owner probably handed on the roll to some later worthy in the same craft. The last owner was much attracted by a roll containing a recipe for "transforming an old man into a youth," and he, or some scribe for him, took pains to copy this at the end of the older material collected by his predecessors.

Meantime much handling and daily use of the document had frayed the beginning of the roll and at least one column of the fine old Book of Surgery containing the title of the book (with perhaps the name of the author) and the beginning of the first case dropped off in tatters.

When at last the village quack himself fell sick and found his art unable to exorcise the demons of disease, his surviving relatives doubtless carried him up and laid him away in a rock tomb in the great Theban cemetery. Luckily for us, they seem to have laid his roll in his coffin with him; for it is hardly likely to have survived in any other conceivable place. There in his tomb it reposed in perfect safety throughout a vast sweep of human history for some three and a half millenniums, from the migrations of the Hebrew patriarchs and the prehistoric wanderings of the Greek barbarians to the American Civil War.

The modern descendants of the old Egyptian quack, searching the tombs for salable plunder, probably found the roll beside the body of their Theban ancestor and saw in it prospects of gain. Unfortunately, however, our information on this point is not conclusive.

The modern vandals stripped off the tatters of papyrus still hanging on the outside, to make it look more "ship-shape." After selling this roll to Mr. Edwin Smith in January, 1862, they patched up another out of indiscriminate rubbish and gave it the appearance of a papyrus roll by wrapping it and gluing in place the tattered fragments which they had stripped off the genuine roll. Two months after the first sale they put this dummy roll also on the market and sold it, likewise to Mr. Smith. Detecting the fraud, Mr. Smith recognized and rescued the new fragments of the precious medical book, thus recovering for science an extraordinary, even though fragmentary, discussion of the heart and its system of canals.

BOTANICAL EXPLORATIONS IN THE ROCKY MOUNTAINS—THE LOLO TRAIL

By Professor J. E. KIRKWOOD

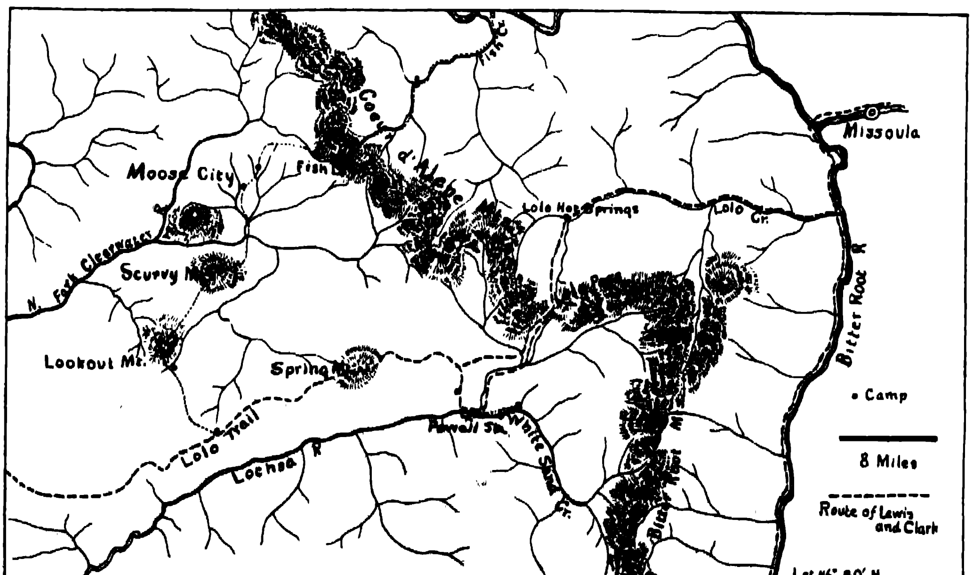
THE UNIVERSITY OF MONTANA

LEAVING Missoula one bright afternoon in August, 1924, we took the river road down the Clark's Fork. The broad intermountain valley lay about us, the fields in mid-harvest. A few miles away the land rose in smoothly rounded foothills, which gradually merged into the timbered mountain sides above, dark green with Douglas spruce and yellow pine. In all directions clearly visible in the grassland, the level shorelines of an ancient lake lay one above another in narrow terraces to a thousand feet above the valley floor.

Below Missoula about twenty miles the valley narrows to a canyon and continues so for the most part during the rest of its course, or until it reaches Lake Pend d'Oreille, two hundred miles to the northwest. The road now becomes an interesting and picturesque drive with a new vista at every turn, as it rises over hills or skirts the stream along narrow ledges.

Forty miles from Missoula a narrow road leaves the highway and after winding about for some time among the pines arrives at Cyr's ranch, which marks one of the starting points for the Clearwater wilderness. Here we left the auto for the pack train and saddle.

Our party consisted of Mr. Vital Cyr, Mr. Richard (Dick) Johnson, Robert Kirkwood and his father, the writer. Mr. Cyr, whom we had engaged as guide and packer, is a member of an old family



MAP SHOWING ROUTE TRAVERSED
ACROSS THE COEUR D'ALENE AND BITTER ROOT MOUNTAINS AND THROUGH PARTS OF THE CLARK'S FORK AND CLEARWATER DRAINAGE.

FISH LAKE,
NEAR THE SUMMIT OF THE COEUR D'ALENE MOUNTAINS.

of French pioneers and well known throughout western Montana for his efficient service to hunters and others entering the extensive wilderness which begins, so to speak, at his back door. Dick, our cook and assistant packer, is a Swede of some forty years, a good fellow, an expert woodsman and a master of camp cuisine. Robert, drawn primarily by the lure of forest and stream, aided materially in the preparation of the collections to which the writer must needs give first attention, although himself far from insensible to the joys of an outing in the deep wilds of the Clearwater. Notwithstanding the unfortunate ending of our trip of the previous year, across the Bitter Roots farther south, we addressed ourselves to this adventure with high spirits.

Cyr's ranch lies at the mouth of Fish Creek, which enters the Clark's Fork from the south. The creek is about thirty miles long from its main source to its mouth, but is fed by many tributaries flowing down from the wooded slopes of twenty-five miles or more of the Coeur d'Alene Mountains. All the way along the swift and stony course its limpid waters are famed for trout, which makes it a delightful place of summer recreation. Along this beautiful stream our trail wound in and out among the pines or followed the ledges above its clear pools. About eight miles above its mouth the stream divides into the North and South forks. Our trail bears to the right and follows the North fork to Clearwater Crossing. Here another trail comes in from Quartz on the railroad northward.

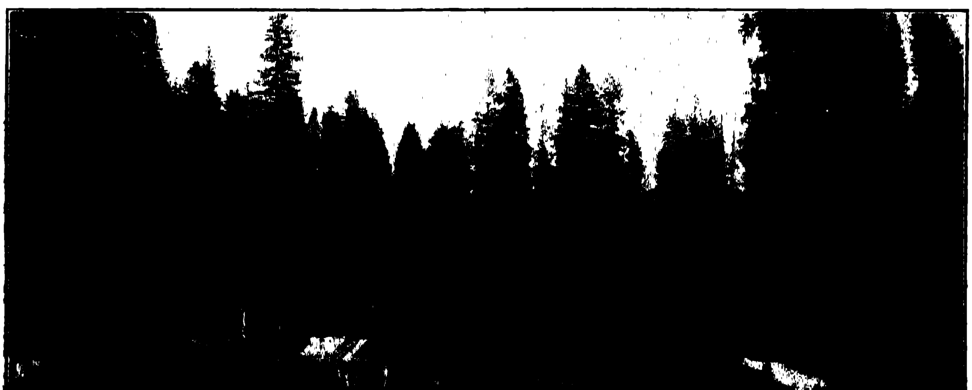
From the mouth of Fish Creek to Clearwater Crossing the vegetation passed through the usual transitions

from the open river valley into the narrow mountain canyons without great increase in elevation. On this day we had hardly ascended five hundred feet, but passed from the arid transition zone of the yellow pine (*P. ponderosa*) into the Canadian or montane zone with its lodgepole (*P. contorta*) forest and accompanying species. The Douglas spruce is freely intermixed along the way. These are the main arborescent species of the uplands. Along the streams the black cottonwood (*Populus trichocarpa*) is conspicuous and overtops the birch (*Betula fontinalis*), alder (*Alnus tenuifolia*) and thick shrubby growth of cornel (*Cornus stolonifera*) and various willows with occasional Cascara (*Rhamnus Purshiana*). In the upper burned region, especially about the Crossing, the southern slopes are strikingly characterized by scattered clumps of mountain balm (*Ceanothus velutinus*).

The Fish Creek trail is one of the historic highways of western Montana. It was built in 1869–70 and served as a means of reaching the then important placer gold camp of Moose City. Though now improved, it still follows in many places the original location and is worn knee deep here and there by years of travel and erosion. Over it passed in that day most of the traffic from the western Montana settlements, long pack-trains of supplies and mining equipment, machinery carried piecemeal on the backs of mules and horses, herds of beef cattle, men on foot and horseback.

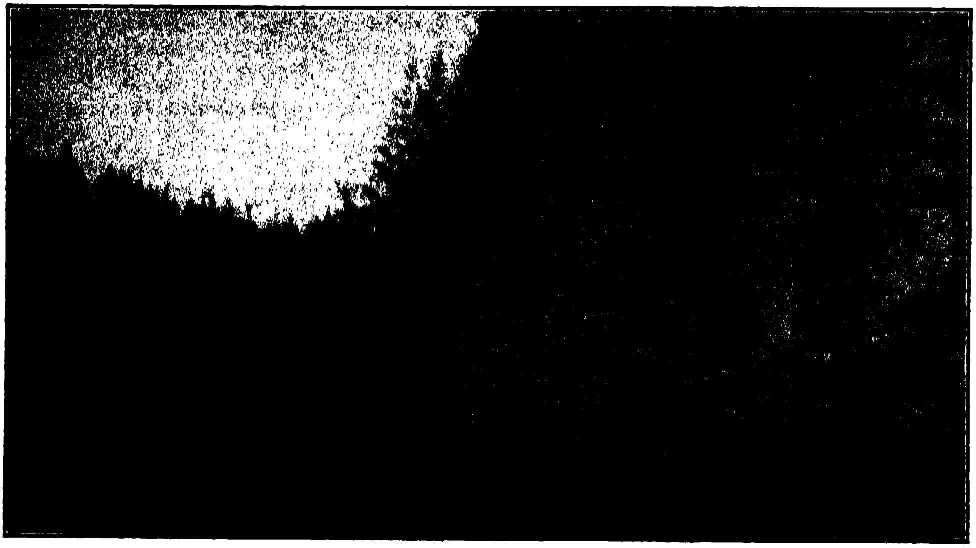
The Crossing marked the end of our first day. Here a log cabin stood hospitably open and near it a corral. Packs off, the horses turned eagerly to grazing and we to our camp and the evening meal. Other parties soon pulled in at this mountain crossroads, which is a favorite spot because of its shelter and feed. Exchange of news and comment was cordial and ready as we cooked and ate together and passed the evening hours.

Rain came in the night and morning opened with a drizzle. From the Crossing the trail rises steadily and often



CAMP ON FISH LAKE CREEK

FOREST OF SUBALPINE FIR (*Abies lasiocarpa*), ENGELMANN SPRUCE (*Picea Engelmanni*) AND MOUNTAIN HEMLOCK (*Tsuga Mertensiana*). IN THE FOREGROUND CONE-FLOWER (*Rudbeckia occidentalis*). NOTE THE POLE TO MARK THE CABIN IN THE DEEP SNOWS.



ALL THAT'S LEFT OF MOOSE CITY

A FLOURISHING GOLD CAMP OF THE SEVENTIES. NOW GROWN UP TO A FOREST OF WESTERN WHITE PINE (*Pinus monticola*).

sharply. It soon enters a thickly wooded glen, where the dank forest supports a thick and tangled undergrowth rising among fallen and rotting logs. Arbor vitae is abundant, indicating the most humid forest conditions that we had yet seen. The northern slope, sheltered from wind and sun with lingering snow and slow evaporation, feeds countless springs and small streams and nourishes a dense vegetation, which in turn reacts on the conservation of moisture in striking contrast to the opposing slopes facing the south.

We ascended over slippery slope and boggy flat, the rain falling almost constantly, and boughs and bushes sagging with their weight of water drenched us anew at every touch. The West Fork was now a roaring series of cascades leaping from ledge to ledge, white with foam. From the cabin we rose three thousand feet and in ten miles crossed the summit and the Montana-Idaho line at 6,400 feet.

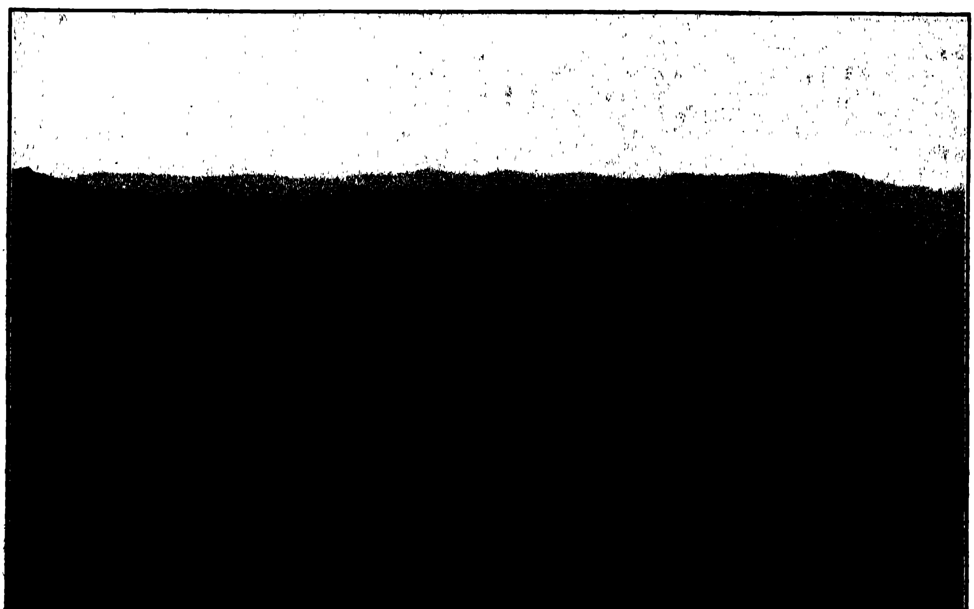
The top of the ridge has a broad and gently rolling contour. Its most interesting feature is a park-like forest of mountain hemlock (*Tsuga Mertensiana*). The thick and dark green foliage, the drooping branchlets and cone-like form of the crown drew our attention at once. Its presence here was expected, although it has a very limited range in the Rocky Mountains and this was near the southern border of its area; from here it extends northward to Alaska and thence south along the Cascade mountains to the high sierras of California. Its occurrence is mostly sub-alpine among spruces and firs, often in bleak and wind-swept situations. It is plentiful throughout the Coeur d'Alene Mountains at altitudes from 5,000 feet upwards, where, however, few peaks rise to as much as 8,000 feet.

In the canyon of a small stream, we pitched camp a few miles below Fish Lake in an open glade or meadow, flanked on the north by a dense forest and open toward the southwest, where rose a high and barren ridge. The heavy precipitation is reflected in the character of the vegetation, which is everywhere dense and luxuriant. This type of meadow is of the "weedy" sort, thickly upgrown with rank herbs, chiefly cone

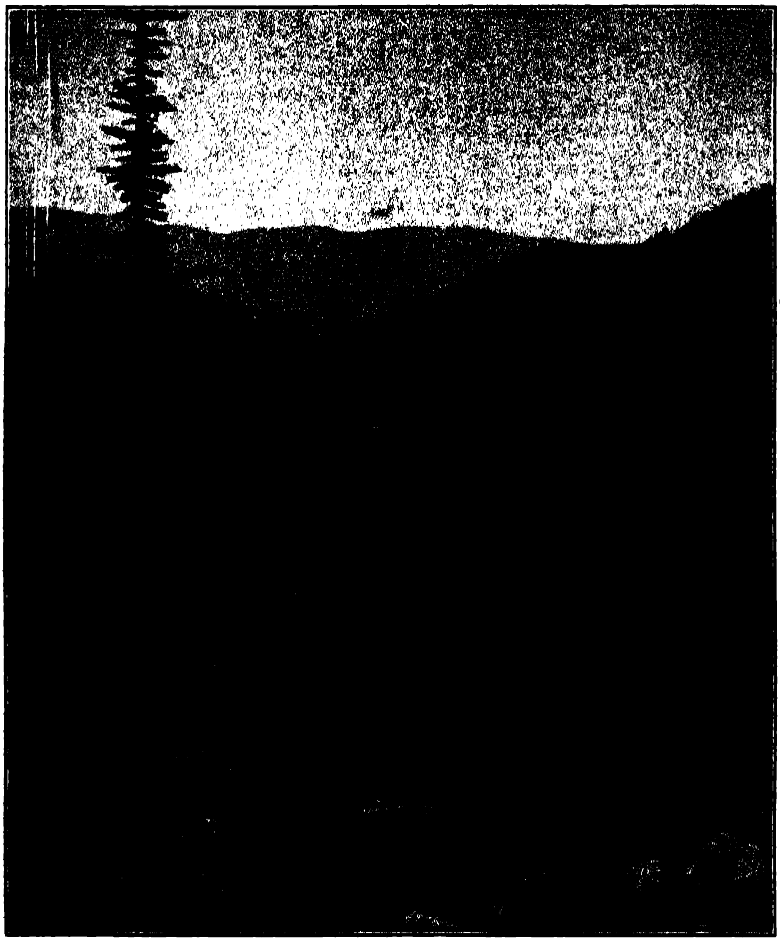
flower (*Rudbeckia occidentalis*) with tall larkspur (*Delphinium glaucum*), monkshood (*Aconitum columbianum*), cow parsnip (*Heracleum lanatum*) and species of *Saussurea* and *Senecio*. In other meadows grass associations are dominant, apparently lacking the conditions of precipitation and humidity necessary for the formation of the weedy type. The forest also is of the moisture-loving species, hemlock, spruce and fir, and where not too dense, with almost impenetrable stands of snow brush (*Menziesia ferruginea*), especially on northern exposures.

The precipitation here is largely in the form of snow, which is said to accumulate during the long winters to depths of ten or fifteen feet. Indications of this fact appear in a novel sort of way. On this flat stood a crude, heavily constructed log cabin, from the roof of which rose a pole like a flagstaff as a marker for the location of the house. Most of the cabins of this sort are built by trappers whose lonely and arduous work takes them over many leagues of the wilderness through the dead of winter. A line of traps may be laid out in a loop of one hundred and fifty miles, with cabins at convenient intervals as refuges at night or in stormy weather. Under this deep blanket of snow the local aspects of the country are obliterated; little creeks, trails, bushes and small trees are entirely covered and the trapper's course is laid by the main topographic landmarks. Coming to the approximate location of the cabin its exact spot may be detected by the pole sticking up through the snow.

Two days were spent at this place waiting for the rain to abate. In spite of the rain some collections were made, but plants collected under such conditions are dried with difficulty. But as time was going by at the rate of $18.00 per day, we could ill afford to be idle and made shift as well as possible. A log fire before the door of the tent spread its welcome warmth through the interior, where driers strung on cords were rendered serviceable and applied with sufficient frequency to dry the specimens



MOOSE CREEK BUTTES AND THE BURNED FOREST.



GEM LAKE UNDER SUMMIT OF SCURVY MOUNTAIN. SUB-ALPINE FIRS

without much delay. On the third night, however, the sky cleared and preparations were made to break camp in the morning.

From this little meadow which we called Cyr's Camp, we proceeded down the little Fish Lake Creek, crossed it and ascended a flank of Osier Ridge. The trail leads now nearly west for about six miles, passing over the summit at an altitude of approximately 6,860 feet. Here the mountain hemlock, Engelmann spruce, sub-alpine fir and white bark pine were growing intermingled in a clean open forest and with scant undergrowth as we swung onto the southern slope. Even in this region, where the precipitation is relatively heavy, though mostly from October to May, the potent desiccating influences of sun and wind leave their imprint on the vegetation in half the circle of a hill.

Turning abruptly south from the west shoulder of Osier, we were soon deep in a forest of white pine (*P. monticola*) and arbor vitae, which grew higher and more dense as we descended to lower levels. So deep was the shade that the sunlight hardly filtered through the dense canopy of branches and the ground was often bare of any vegetation, save an occasional toadstool, which rose out of

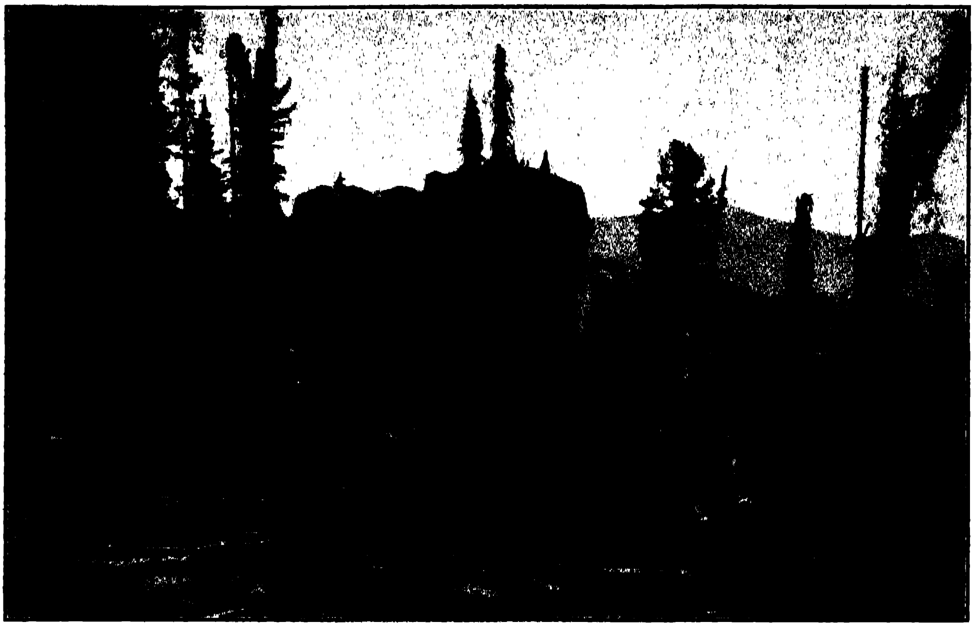
the mat of decaying leaves. About us on every hand the thick gray columns ascended to somewhere in the labyrinth of foliage between us and the sky. In the jungle to our right the trickle of a little stream was heard and the remains of crude shelters of leaning poles appeared among the trees. Dick informed us that we were at "Shina" Spring and recounted to us some of the early history of the Chinese in the mining locality which we were now entering.

A night spent at the Alma Mine on Osier Creek, a few collections made along the stream and we resumed our journey. In an hour or less we came to the site of old Moose City. One tumbledown log cabin now remains of all that once was a roaring gold camp of over 3,000 people. A vigorous young forest of white pine of thirty to forty feet now stands thickly over the streets and lots of the old town, and nothing breaks the silence save the native cries of the wilderness, which has reclaimed its own. Here in the early seventies the life of the camp was at its height. The gold of the gravels, rich in places, finally played out and the scene relapsed into the silence from which it came. Brought about by natural forces the concentration of the gold in these narrow gulches has led to hopeful exploration of the surrounding hills in search of the mother lode but without success. Probably the hope is not well-founded, since the drift of the free gold to the stream gravels would tend to magnify the prospect.

From Moose City our way lay down Independence and Moose Creeks to Kelley Creek, which we crossed just above its junction with Moose. We passed a fire camp and a new burn which had cleaned up a few hundred acres of dead timber, killed by the fire of 1910. Viewing the rest of the desolate waste of dry and bleaching skeletons we could not feel much regret at the riddance of rubbish that littered the ground. It was fourteen years since the first fire had swept through, and the trunks of a fine forest of white pine and cedar stand thickly over hundreds of square miles of the Clearwater country. From high points, often as far as the eye can reach, this scene of desolation spreads with unvarying and depressing monotony.

In this burn the dead trees are now rotted in the ground and slight winds bring them down in numbers. Eventually they will form an intricate and impassable tangle of debris, dry and splintered, a mass of material ready for a fire more intense than the first. And fires are inevitable. A single electric storm may start several of them. Given what may easily happen—a dry season, electric discharges accompanied by little rain, a high wind, fires started in inaccessible places and no fire-fighting crews or equipment would be able to cope with the situation.

The burn has come up to a growth of willows and other shrubs, native herbaceous plants and a coniferous growth of little consequence in many places because of its sparseness and the inferior species it represents. But whatever the growth under these conditions it seems to be foredoomed. It hasn't one chance in a hundred of coming to maturity before being caught by a devastating fire. Every year is an added risk, augmented by the time represented in the young growth. With such reflections in mind one can hardly escape the conclusion that the earlier the slate is wiped clean the better. The menace in such a fire is that it is likely to spread to new areas of green timber, and this menace, it must be admitted, is considerable. A cleanswept area of course must be planted if too large to be seeded from the side which, over such an area as the Clearwater, is impossible. Planting, truly, is costly. The only question is which is likely to be more costly, trusting to chance in the face of serious hazards, or allowing fires to clean up the deadened areas. Fire-fighting also is costly and the question



THE DEVIL'S CHAIR
SCENE ALONG THE LOLO TRAIL.

may be asked as to whether the present growth with the ultimate risks involved is worth the outlay it takes to protect it.

The dominant shrubs throughout the burn are Scouler's willow and thimble berry. Along the stream hawthorn, cornel, alder and willow grow in dense thickets. A few scattering saplings of lodgepole pine and here and there a young white pine could be found. Hardly a single mature green tree appears within our range of vision except toward some of the distant and higher elevations.

From Kelley Creek we ascended a well-built trail along the northwest slope of Scurvy Mountain. Passing through the burn we came later upon scattering hemlocks and firs mingled with white bark pine and patches of alder, spiraea, mountain balm; and bear grass constituting most of the undergrowth. Near the summit of the trail a cabin sheltered two young men who kept the lookout station on the peak a quarter of a mile or so to the north. We were heartily welcomed and offered such accommodations as the place afforded. An excellent spring, some shade and plenty of feed decided the matter and we prepared to sojourn here the balance of this day and the next.

Under the peak of Scurvy Mountain, on the east side about six hundred feet down, nestles a beautiful little lake. As the map assigns no name the writer suggested Gem Lake as an appropriate designation. It is fed by springs and melting snows and empties by a little stream which descends by a steep and narrow gulch to Kelley Creek. Around this lake grow grasses, sedges, peat moss entangled with violets, heaths (*Ledum, Kalmia* and *Menziesia*) and willows, and back of all a fringe of tall and spire-like firs. The cold waters of the little lake are deep and clear, and near the shore float the long slender streamers of a delicate bur-reed (*Sparganium angustifolium*).

From Scurvy Mountain our way led south over the top of Lookout Mountain at 6,900 feet and thence easterly to the

Lolo Trail at Indian Graves. Most of the ground traversed was through old fire-killed timber, under which a vigorous growth of thimbleberry and willows occupied most of the ground, save where acres of *Gnaphalium sulphurescens* gave a whitish cast to the landscape. Little of interest marked these miles except around our evening camp at the head of Monroe Creek, where a beautiful meadow, bedecked with the colors of groundsel, monkey flower, harebell and gentian, was divided by a clear, little stream fringed by low sedges. Like an oasis in the desert, this field of green and blue and gold gave us refreshing rest in the midst of a wide wilderness of death.

The Lolo Trail, which we touched for the first time at Indian Graves, is an ancient Indian highway which follows the divide between the North Fork of the Clearwater and the Lochsa. It was an old trail, no one knows how old, when Lewis and Clark were the first white men to travel it in 1805. It was the main route from the lower Snake River region and the Nez Perce country to the plains of the Missouri via the Clarks Fork and Blackfoot Rivers. Over this trail Chief Joseph and his people made their memorable march. The feet of countless ponies have cut deep into the soil, have abandoned these ruts and made others alongside. Hoofs and travois have worn a wide road, keeping in true Indian fashion to the highest ground, which was often steep and difficult but comparatively free of brush and fallen timber.

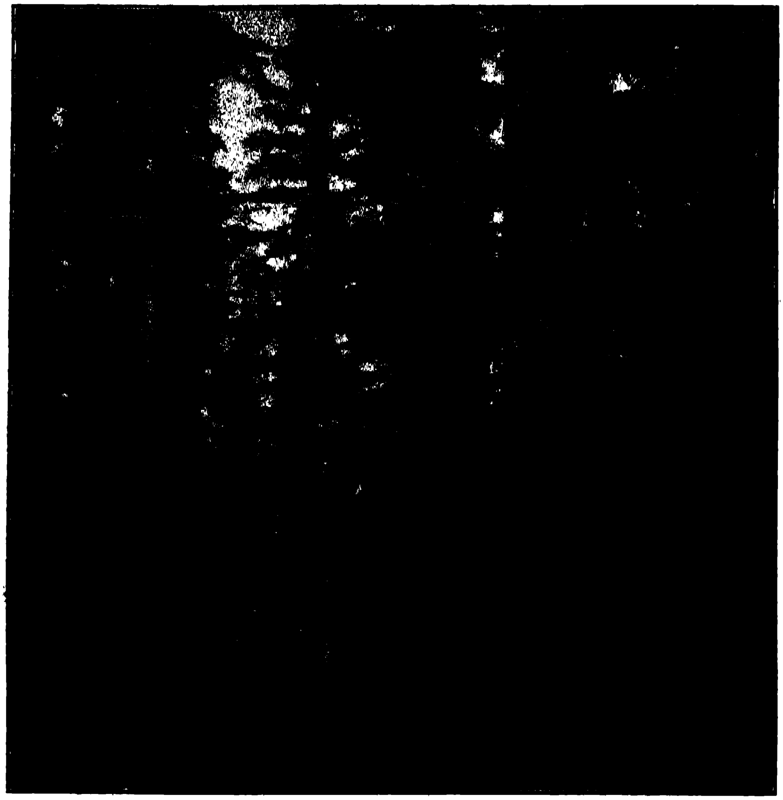
From Indian Graves we followed the trail up the ridge to the northeast. Most of this ridge still bears its virgin trees and many a mile of the trail lies through beautiful forest aisles. The mountain hemlock and white pine in more favored places form high forests with cool and deep shade. On the drier ridges they give place to lodgepole pine in mature open stands, with few companions save the widespread and dominant bear grass. In younger stands of lodgepole the low red huckleberry (*Vaccinium scoparium*) is usually the prevailing ground cover, the bear grass coming in later. The two, however, often appear together under the lodgepole canopy. Sub-alpine fir and spruce also abound, especially in gulches and wet soils.

Impressive rock formations appear. The granite weathers in massive columns and huge boulders, standing out upon the mountain side or rising isolated in the midst of the forest. One group of unusual form is known as the Devil's Chair. They were not observed on the Selway or the Clearwater and seem for some reason to occur along this divide and in near localities.

This was a long day's trip. Twenty miles with a pack outfit over a rough trail is about enough for one day. Feed without water, or water and no feed was an impossible camp, so we pushed on, the longest twenty miles it seemed that we had seen in many a day. The sun was sinking low, so we made camp on top of Spring Mountain. A spring by the trailside about a quarter of a mile below the top of the hill must be the feature alluded to in the name, for no other water was found. Some forage was scattered among the tufts of bear grass, but evidently not much, for the horses dispersed widely in search of it. The wind blew cold, and without shelter of hill or forest we made the best of an uncomfortable camp. Lewis and Clark stopped here on their return journey in 1806. This being in June, the young herbage seems to have been sufficient for their stock, but in the fall of the year we were not so fortunate.

No regrets were felt at leaving Spring Mountain. We were early on the trail, which nearly all day led through green forests. The beautiful scenes along this ridge still linger in the memory, although many of them are preserved in more durable form.

At one point that day we met a solitary traveler with a lone pack-horse on



THE LOLO TRAIL

FOREST OF MOUNTAIN HEMLOCK. UNDERGROWTH OF SNOWBRUSH (*Menziesia ferruginea*) AND BEAR GRASS (*Xerophyllum Douglasii*).

his way to Lewiston, Idaho, apparently an itinerant prospector, whom our packers facetiously referred to as a "coffee cooler." Having exchanged the usual salutations we improved the opportunity to inquire as to the trail that lay ahead of us and to locate, if possible, some of its doubtful points. He volunteered the information that he had been misdirected via the river trail and had to climb up out of the canyon onto the ridge. "I just came up that ——— hill," he added, with further maledictions upon his misinformers.

Evidently the trail which he so feelingly described was the Powell branch of the Lolo Trail, which led to Lolo Pass by way of the river in the interests of salmon fishing, as recorded by Lewis and Clark. The other branch kept straight on along the highlands. This fork of the trail we had been looking for for some time and were somewhat uncertain lest we had passed it, as some of the cutoffs were unmarked and indistinct. We were now set at rest by the stranger as to the location of this point and arrived at Powell Junction about two P. M., where we were to await the arrival of the pack train.

As luck would have it, we found the ridge trail beyond the junction blockaded by fallen timber and so were compelled to take the route via the Lochsa, down the trail that our chance acquaintance had recently ascended, and soon found for ourselves that it was quite worthy of his ardent comments. Straight

down Parachute Hill it goes, a quarter mile perhaps at the steepest, and the horses had little to do but slide.

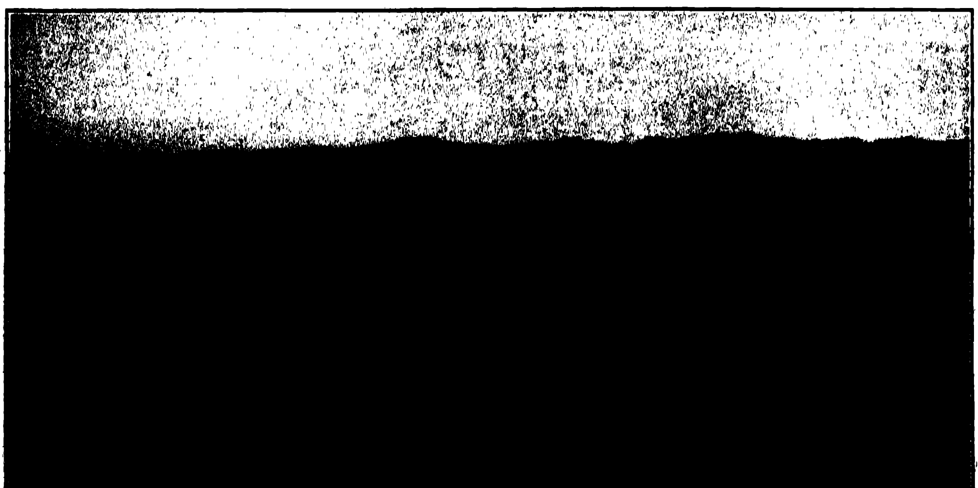
At the bottom of the hill ran a clear little stream flanked with alders, and in an open glade of the forest we pitched camp. On a big spruce under whose sheltering arms we threw our packs were carved the words "Bear Camp." Nearby was a muddy swale, in which were several slimy bear wallows, whence, probably, the name. Tall firs, spruces and lodgepole pine surrounded us and we were in quite the opposite condition to that of the previous night on Spring Mountain. A high wind roared in the trees on the ridges above, but not a breath of air stirred about the camp. Nevertheless a thick layer of ice formed in the water pail that night, the 29th of August.

From Bear Camp the trail drops one thousand feet to the Lochsa River. The grade is easy and the way lies through deep forests of grand fir and arbor vitae. Here and there beautiful open glades abound in fresh and luxuriant vegetation despite the cold nights. In the deep shade of the forest, however, little grows save a few pale ferns, which is in marked contrast to the plant life of the day before at 2,000 feet higher, where lodgepole and bear grass prevailed in the open forest, or in the burn where mountain balm and spiraea bordered the trail, mingled with asters and fleabane.

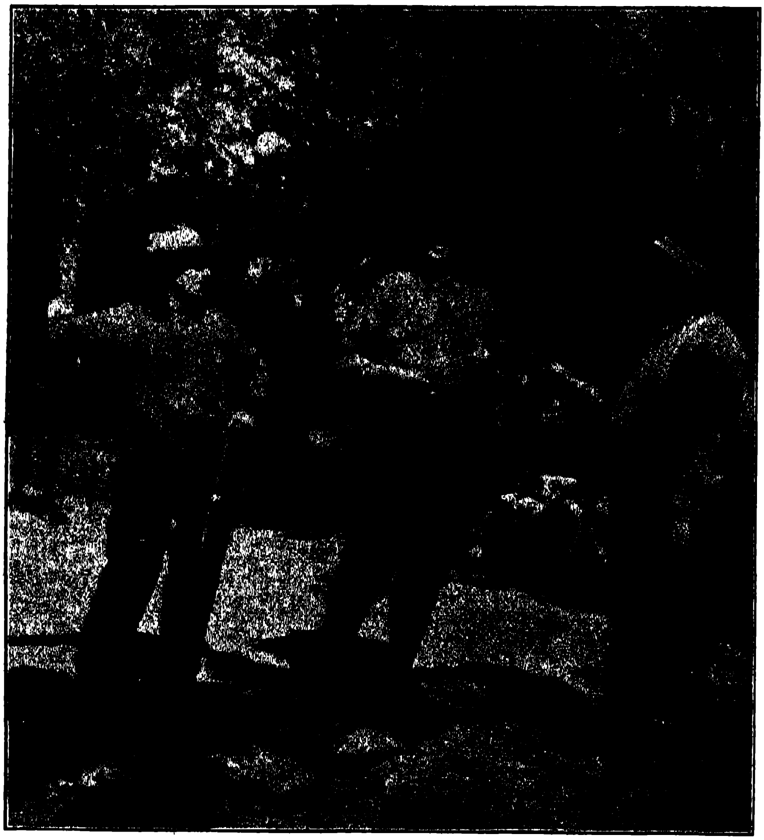
An hour or two brought us to Powell Ranger Station, where a well-built log house and corrals stood on a flat near the river. Here the trails are wide and improved, of easy grade, crossing the stream by bridges instead of fords, and providing facility in the movement of supplies, so essential in the case of fire.

A short distance above Powell Station the Crooked Fork and White Sand Creek unite to form the Lochsa River. They are both beautiful streams and with their numerous feeders drain over seventy miles of the western slope of the high Bitter Roots and Coeur d'Alenes. At this time of year both streams are easily fordable at most places, but the broad stream beds, bare rocks and gravel bars show that a huge volume of water pours down these channels from time to time. Their clear cold waters flow from numberless alpine meadows and little hidden lakes.

A road is now building down the Lochsa from Montana into Idaho. Sad fact! The days of the virgin wilderness



KELLY CREEK BASIN FROM SCURVY MOUNTAIN



AT THE END OF THE TRIP
AT LOLO HOT SPRINGS. FROM THE LEFT, RICHARD JOHNSON, THE WRITER, AND VITAL CYR.

are numbered. Nothing in park or garden or human haunts has quite the charm of nature's untarnished beauty in these remote wilds, where flowers bloom untrampled and the forest primeval has never felt the ravages of the axe and saw. The road brings the auto, and the auto brings the tourist and the camper. Every lovely streamside will be littered with papers and tin cans. In autos come loads of fishermen who ply their rods up and down every stream until the trout vanish. Come the hunters and the despoilers until nothing is left but the landscape. All these things must be, of course, but the nature lover views the passing of the primitive solitudes with a pang of regret.

Cabin Creek is a little stream that tumbles noisily over many boulders on its way to White Sand. Here we threw off the packs and let the horses go. The bright sun of noon shone down through the pines and scattered checkered shadows over the ground. It was a beautiful day. The flashing riffles of the White Sand invited our flies and the willow copses and verdant banks promised interesting additions to the plant press.

The trail from Powell Station to Lolo Springs follows the left bank of the Crooked Fork. At Brushy Fork it enters Pack Creek Canyon and rises steadily to its junction with the old Lolo Trail near Packers Meadows. Again the

day was spent in the deep forests, which filled the gulches with cedar and fir. Occasional burns were passed, but the trail was fair and we made good time. Gradually the roar of Pack Creek became less vociferous, the way less steep, the bottoms broadened into reedy flats and low willow thickets. We were nearing the Meadows. Here the forest grew silent, and as the sun sank toward the wooded ridge to the west we emerged upon the edge of an extensive grassy area which marks the approach to Lolo Pass from the west. Here we pitched camp where Pack Creek had dwindled to a mere rivulet and spent the evening hours exploring the botanical possibilities of the flats, adding to our collections gentians, asters and other plants which we had not met before.

Packers Meadows is a beautiful area of grassland surrounded by pine forests. A meandering stream makes its sluggish way westward and the trail cuts across in a northerly direction to drop down on the Clarks Fork drainage. So slight is the rise that it is hardly perceptible, and only when the water is seen flowing the other way does one realize that the divide has been passed. The altitude of the pass is only 5,254 feet. Lewis calls attention to the abundance of the Camas in these meadows and to the evidence here of frequent encampments of Indians in their journeys along this trail.

The night was clear and cold and a heavy frost descended upon our beds. The tinkle of the horse bells came down the meadow, and as the fire flickered out we resigned ourselves to dreams of marching figures in buckskins and furs, who through the past have made history along this storied highway.

All too soon, however, the sound of a crackling fire and of Dick operating among the camp utensils roused us to consciousness of another day. From blankets to creek on a cold morning is an abrupt transition but invigorating. How cold water washes the sleep out of the eyes! The blood tingles and the zest for breakfast brooks no delay. Flapjacks, butter and syrup, bacon, trout and coffee—what more is needed for the beginning of a perfect day! Came once more the rolling of blankets and the stowing of packs, the rounding up of reluctant horses and the cinching of saddles. Once more we strung out along the old trail, across the wide meadow and through the Pass.

Lolo Hot Springs are described in the journal of Lewis and Clark, who passed here on their westward trip September 13, 1805, and on their return camped at this spot on June 29 of the following year. The Indians were then impounding the waters of the hot springs and using them as baths, and now a hotel and bath houses and a considerable cluster of cabins and tents mark the site of a rapidly growing summer resort within easy drive of Missoula.

The Lolo is one of the larger creeks flowing east out of the Bitter Root Mountains. One fork of it rises near Packer's Meadows, which, added to many others, makes a beautiful little stream which goes gliding over its gravels toward the Bitter Root River. Its fall is moderate, so it is not a foaming torrent like those that pour down the steeper gulches. Before the building of the road, wagons followed the stream bed much of the way, the waters being shallow, and even now we cross it frequently on low wooden bridges. As it curves from side to side we catch vistas down its course with its clear waters dancing and sparkling in the sun, its banks fringed here with alders, there with broad gravel bars or a green flat. Shallow pools are filled with cresses or the feathered stems of the white water crowfoot (*Batrachium*), bordered by yellow monkey flower (*Mimulus langsdorfii*). Bunches of senecio (*S. triangularis*) with yellow flowers rise here and

there, and occasionally a tall monk's hood (*A. columbianum*) lifts a panicle of purple flowers.

The canyon of the Lolo lies between bluffs that rise abruptly and then fall away in more gentle slopes to the more distant and higher elevations. Their slopes are timbered except for minor areas long since swept by fires and now occupied by shrubby growth. As the course of the canyon lies east and west one slope is shaded while the other receives the perpendicular rays of the summer's sun. The comparatively light rainfall leads to a strong differentiation of the vegetation in relation to exposure. North facing slopes are thickly forested along the whole length of this canyon, the opposite slope sparsely wooded, mostly with yellow pine and Douglas spruce, increasing in density with higher and more humid levels. In the upper canyon both slopes are more nearly alike, but toward the mouth of the valley even the drouth-resistant pine gradually yields to bunch grass and sage (*Artemisia tridentata*) or rabbit brush (*Chrysothamnus nauseosus*).

Ten miles from its mouth the canyon opens out into a valley, at places half a mile in width, occupied by attractive little farms with an air of prosperity. Their fields, now sere in the approaching autumn, were lately occupied by waving grains and rich meadow grasses. Orchards laden with ripening apples and fat stock grazing in the fields fill the picture of rural life. Only one blight rests upon this pretty scene, the specter of the spotted fever. Now and then, not often, but here and there comes the fatal touch of this mysterious malady.

Mount Lolo, a few miles to the south, rises to 9,000 feet, bold and massive. Its forests are bluish in the early autumn haze. Above its broad shoulders rises a rounded rocky summit, in the lee of which lie a few drifts of last winter's snow. In a few weeks the larch leaves will be turning yellow and then the lower slopes will display the location of *Larix occidentalis,* while around the summit like a wreath at the timber line will appear in equally brilliant color the zone of *Larix Lyallii.* Between these two will extend the broad and uninterrupted belt of dark-hued pine and spruce.

We are still upon the historic route of Lewis and Clark. In their westward trip of 1905 and their return in 1906, they traversed the whole length of Lolo Canyon. At the mouth of the canyon now stands a bronze tablet to the memory of these intrepid explorers. The main features of the landscape and the flora probably remain much as they saw them, save for the towns, farms and roadways which even yet have not penetrated deeply into the wilderness nor ventured far from the main streams and ancient highways.

GRASSHOPPERS AND THEIR ALLIES[1]

By Dr. ANDREW N. CAUDELL

Of all the insects which annoy mankind none do more real and serious damage than grasshoppers. From time immemorial these insects have devoured the vegetation of the earth, and the biblical narratives of havoc wrought in early days describe invasions no more serious than others of almost annual occurrence in some part or other of the world at the present time.

The damage done by grasshoppers consists chiefly in the destruction of grasses and of grains which are devoured by them; but some years ago there came to my attention an authentic case of a ranchman in Montana having lost four cows from their having eaten large quantities of grasshoppers which they were unable to digest. Chickens also were killed by eating too many of the insects, though in moderate quantities grasshoppers form a very good food for poultry.

The number of individual grasshoppers in a swarm is so very great as to seem utterly incredible. In 1898 a swarm passed over a ship off the Great Hanish Islands in the Red Sea which was estimated to contain no less than twenty-four thousand two hundred and forty billions of individuals weighing, at sixteen to an ounce, about forty-two thousand five hundred and eighty millions of tons. It is recorded that people have been made seasick by looking at masses of young grasshoppers which caused the surface of the ground to resemble the rolling billows of the sea.

In the early days of our own history our western states were occasionally overrun by hordes of grasshoppers which in a single night would entirely destroy extensive fields of grain, and in their migratory flight such swarms were so dense as to obscure the light of the sun for hours at a time. In passing over high mountains these flights encountered low temperatures, and as a result millions of the insects fell benumbed onto snow fields where they became embedded in the snow and eventually became incorporated in glacial ice. The Grasshopper Glacier in Montana is so named from the myriads of these insects scattered through its ice like raisins in a cake.

Fortunately conditions now have changed so that such immense invasions of grasshoppers no longer occur within our borders, though vast damage still is almost annually done through the ravages of a number of our native species.

So far it has not been possible wholly to subjugate our grasshopper enemies, but by the constant warfare waged against them the damage has been very materially lessened.

To some extent man counterbalances the damage done to his crops by grasshoppers by making use of them as food. Indeed, in some parts of Africa and Asia at the present time they are a very important article on the bill of fare of many native peoples. Thus in India many of the delicious curries are composed in greater part of grasshoppers ground up. In Arabia and other regions ground grasshoppers are used as a substitute for flour. In parts of Africa even the eggs are used, boiled up into a sort of soup.

It is prejudice alone that causes most people to look with disfavor upon insects

[1] One of the Smithsonian series of radio talks arranged by Mr. Austin H. Clark, and given from Station WRC, Washington.

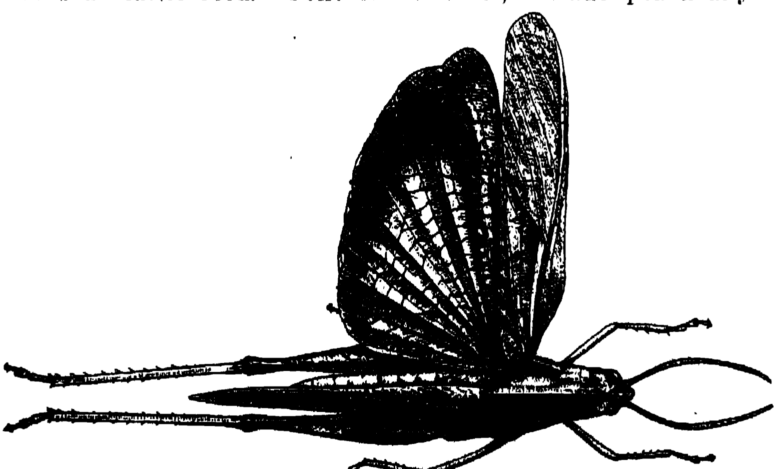
A GRASSHOPPER (*MELANOPLUS FEMURRUBRUM*)
ONE OF OUR COMMON INJURIOUS GRASSHOPPERS.

as food. Some of the leading entomologists of the country, speaking from personal experience, assure us that well-prepared grasshoppers form a very palatable dish. Why should well-cooked grasshoppers be less agreeable to us than raw and living oysters?

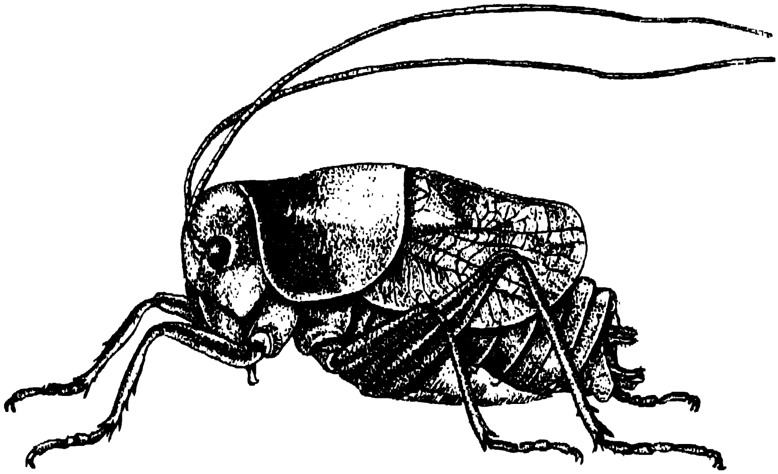
Although the most important use made of grasshoppers is to serve as food for man, they have been utilized in other ways. Great masses of them, at least as many as eighteen tons in a single year, have been shipped from South Africa to Holland, where the oil extracted from them was used for a special sort of airplane, it being particularly well suited for this purpose as it retains its liquid form at very high altitudes, and the residue was used as cattle feed. Tons of grasshoppers are also annually used as chicken feed.

Most grasshoppers are somber in color and are not especially attractive insects. But some vie with the brilliant butterflies in their gorgeous coloration, while others are provided with ornamental, sometimes bizarre, crests or other protuberances which impart to them an interesting or grotesque appearance.

Closely related to the grasshoppers are the katydids (Tettigonidae), insects scarcely less well known than the grasshoppers themselves. There are many different kinds of these. Most of them are green in color. Among them are some of the most renowned of the insect musicians, and these, together with the crickets, include practically all of the



A GRASSHOPPER (*TOMONOTUS FERRUGINOSUS*)
OCCURRING IN THE SOUTHWESTERN UNITED STATES, WITH THE LEFT WING SPREAD.



A SHORT-WINGED KATYDID (*CYPHODERRIS MONSTROSA*)
OCCURRING IN THE NORTHWESTERN UNITED STATES AND CANADA.

music makers which render our autumn evenings and nights so harmonious.

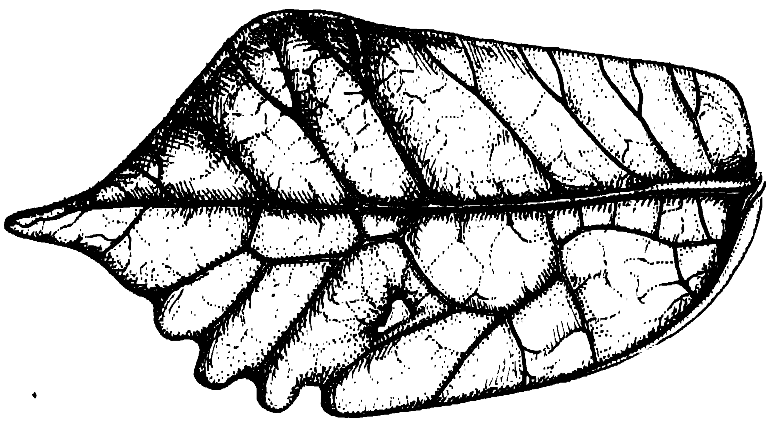
The music of the katydids is produced by special sound organs on the wings of the males, the females being without such special instruments and therefore incapable of producing loud notes. The fact that only the male is musical is not generally known. For instance, one poet commences one of his effusions "Thou art a female katydid, I know it by thy thrill," which may be good poetry, but is certainly deplorable entomology.

The true katydid, the one made famous by poets and classic writers, is by no means the one most generally known. In areas overgrown with tall trees this renowned musician passes its life entirely among the upper branches and seldom, if ever, descends voluntarily to the ground. With its broad, but rather short, wings it is incapable of sustained flight, its wings acting more as the planes of an airship and permitting a safe landing in case of necessity. Other longer winged katydids are more familiar to most of us, and are the ones most often seen and heard.

Most katydids lay their eggs in the pith of plants, under sheaths of grasses,

A WINGLESS KATYDID (*DAIHINIA PHRIXOCNEMOIDES*)
OCCURRING IN NEW MEXICO AND TEXAS.

between the two surfaces of leaves, or in similar situations, but a few lay them on the surface of leaves, or even in the ground. Unlike the female grasshoppers, which have no elongated egg-laying organ, the lady katydid possesses a sword-like appendage at the end of the body by means of which she inserts her eggs, one at a time, into the pith of plants or other places. This sword-like organ is in most kinds of katydids long and slender, sometimes longer even than the body itself, but in some it is short and stout. One of the most astonishing examples of what one of these insects is capable of doing in the way of splitting substances into which it desires to place its eggs came recently to my attention. We all know on what compact and very thin paper railroad timetables are printed. One would scarcely believe it possible to split a piece of such paper, but a large green katydid from California actually performed this feat and inserted four or five eggs in the slit. It is necessary to see this piece of work to believe it possible.



THE LEAF-LIKE FORE WING OF A KATYDID (*TYPOPHYLLUM UNDATUM*)

Katydids are not so renowned for their intelligence as are the ants and wasps, but the following illustration shows how one of them succeeds in outwitting the wily ant. In the tropics vast hordes of ants, the so-called army ant, march in almost solid masses through forests and over fields killing every living thing that comes their way. Few insects can escape one of these marauding armies, as they are killed by the ants if they remain on the ground or in the bushes or trees, while if they take to flight they are caught by insectivorous birds. One large and long-legged katydid, however, has acquired wisdom which enables it to escape death where others perish. This is accomplished by remaining on the ground with the body elevated as high as the long legs will permit and standing perfectly still. The ants march by the immovable stilt-like legs mistaking them for grass stems, and thus the cunning katydid escapes its ferocious foes.

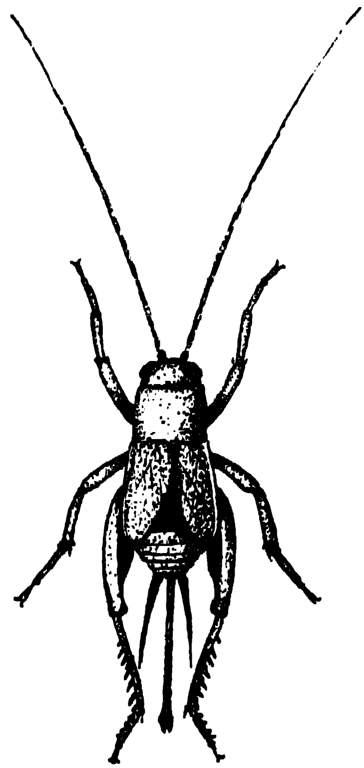
Another kind of katydid under like circumstances is recorded as escaping injury by lying perfectly still. This particular kind is shaped and colored exactly like a leaf. This mimicry is so perfect that the leaf-like wings even have veins just like those of a real leaf and also transparent spots as are so often seen in leaves.

Some of these leaf-mimicking katydids are green, like living leaves, and some are brown just like dead dry leaves. There are other equally wonderful examples of mimicry in this interesting group of insects.

Related to the katydids we find the crickets (Gryllidae), insects well known to almost everybody. As in the case of the grasshoppers and the katydids, most of the crickets have long hind legs fitted for jumping. Like the katydids the females of most crickets have a long egg-laying organ, and the males are notable musicians.

A large African cricket (*Brachytrupes megacephalus*) is said to produce notes capable of being heard for a mile. But it is not such loud notes that have gained for crickets their reputation as musicians, it is rather the low musical tinkle of the smaller forms such as our common tree crickets. The melody of cricket trills vies with that of the notes of katydids in calling forth the approbation of the listener. In parts of Asia crickets and katydids are kept in small cages as we keep canaries, and such caged insects are commonly seen offered for sale in the public markets.

Aside from their musical accomplishments, crickets serve to amuse mankind by the display of their belligerent and pugnacious dispositions. The fighting instinct at once asserts itself when males of certain kinds are brought together. In China fighting crickets are very popular, and are cared for as carefully as we care for our race-horses. A champion cricket gladiator is said to sell for as much as fifty dollars, and large sums are

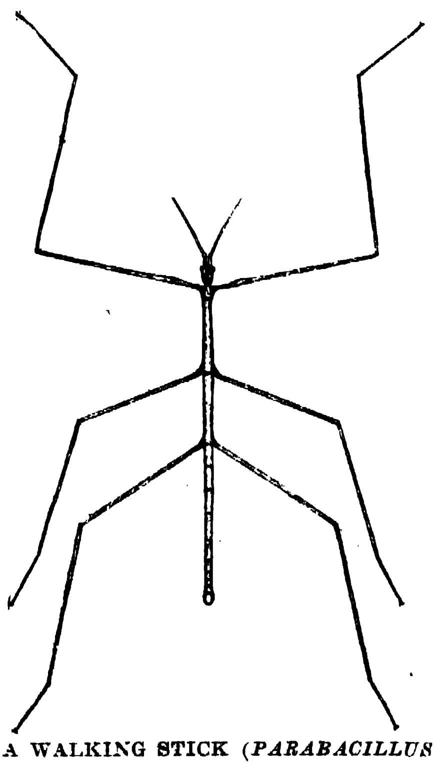


A CRICKET (*GRYLLUS ASSIMILIS*)
WITH A WIDE DISTRIBUTION IN NORTH AND SOUTH AMERICA.

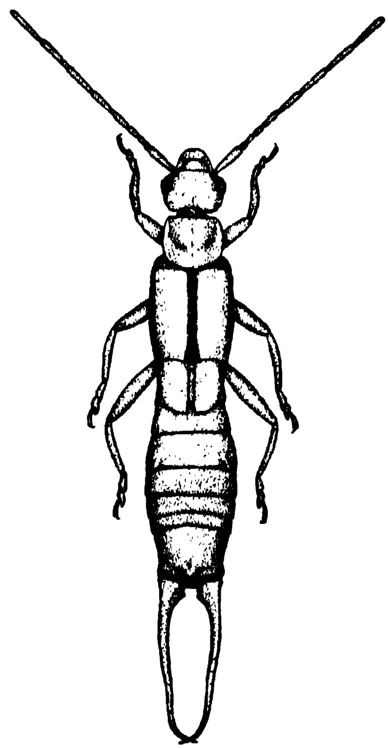
A MANTIS (*PSEUDOVATES TOWNSENDI*)
FROM MEXICO.

won and lost on the outcome of cricket fights.

While by devouring his crops the grasshoppers do the most material damage to man, there are certain relatives of these insects which are even better known as pests, especially to housewives. These are the cockroaches (Blattidae). The cockroaches do not have the hind legs adapted for jumping, like the grasshoppers, katydids and crickets. There are many kinds of roaches, especially in the warmer countries. Two kinds are especially well known and hated by the householder. These are the croton-bug or German roach, a small brown sort with two black stripes on the back be-



A WALKING STICK (*PARABACILLUS COLORADUS*)
FROM COLORADO.



AN EARWIG (*CIPEX SCHWARZI*)
FROM CUBA.

hind the head, and the black roach, a larger kind in which the female is provided with much shortened wings. Other larger long-winged roaches often occur in buildings, sometimes in great numbers, but it is the two just mentioned that are most often found in homes.

There are three other groups of insects which are related to those previously discussed which, though quite as interesting, are of less real importance to us. These are the mantises or "rear-horses" (Mantidae), which feed on other insects, the walking sticks (Phasmidae) which are leaf-eating, and the earwigs (Forficulidae).

TOBACCO AND SCHOLARSHIP

By Dr. J. ROSSLYN EARP

ANTIOCH COLLEGE

"THE brain contains three kinds of cells: memory cells, intelligence cells and conscience cells," said my visitor. I did not deny it. After all she is a prominent official in the Anti-Tobacco League of this state. All three kinds of cells, she says, are ruined by tobacco. Yes, sir, she has seen them herself.

This little incident, extracted from a somewhat lengthy interview studded with such doctrinal gems, may serve to demonstrate how far removed is the great tobacco controversy from the ordinary paths of science. Among the innumerable articles that have been published for or against the smoking habit it is necessary to make a long and tedious search if we would discover anything of real worth.

One aspect of the subject which, not unnaturally, has attracted a good deal of serious academic interest is the relation of smoking to scholarship. Eighteen years ago E. L. Clark[1] observed a great difference in scholastic achievement between students who smoked and those who abstained. In a college of 201 men 69 per cent. of the non-smokers and only 18 per cent. of the smokers won honors in scholarship. The excellence of non-smokers in scholarship has been noted for college students by various other investigators, among them Jay W. Seaver[2] (Yale), George L. Meylan[3] (Columbia) and W. L. Holt[4] (University of Tennessee). The latter emphasizes particularly the failure of the smokers. Similar studies have been made for high-school students, the latest and most important being that of M. V. O'Shea[5] covering a large material (about 70,000 boys). There is remarkable agreement on the general conclusion that non-smokers, whether at school or in college, are better scholars. Three series of observations made at Antioch College, one in 1924, one in 1925 and one in the present year, have convinced the writer that this difference is constant and that it is statistically significant, since the difference in performance of smokers and non-smokers is of an order that could not be accounted for by chance alone. Figure 1 shows graphically how the non-smokers (continuous line) excel in high scholarship, while the smokers (interrupted line) are more numerous in the lower grades. This figure is taken from the study two years ago. The mean grades on that occasion were as follows:

	Mean Grades
177 Smokers	3.51 plus or minus .03
176 Non-smokers	3.14 plus or minus .03
Difference	.37 plus or minus .04

There arises the question as to whether the tobacco causes low scholarship or whether there are one or more attributes closely correlated both with smoking and with low scholarship. Dr. Meylan believed that smokers are more idle. It might be either that the smoking habit

[1] Clark, E. L., "Effect of Smoking on Clark College Students," *Clark College Record*, 1909, IV. 91.

[2] Seaver, J. W., "The Effects of Nicotine," *The Arena*, 1897. 17. 470.

[3] Meylan, G. L., "Effects of Smoking on College Students," *Popular Science Monthly*, 1910. 77. 170.

[4] Holt, W. L., "Educational Research and Statistics," *School and Society*, 1921. 14. 136.

[5] O'Shea, M. V., "Tobacco and Mental Efficiency." New York: The Macmillan Co., 1923.

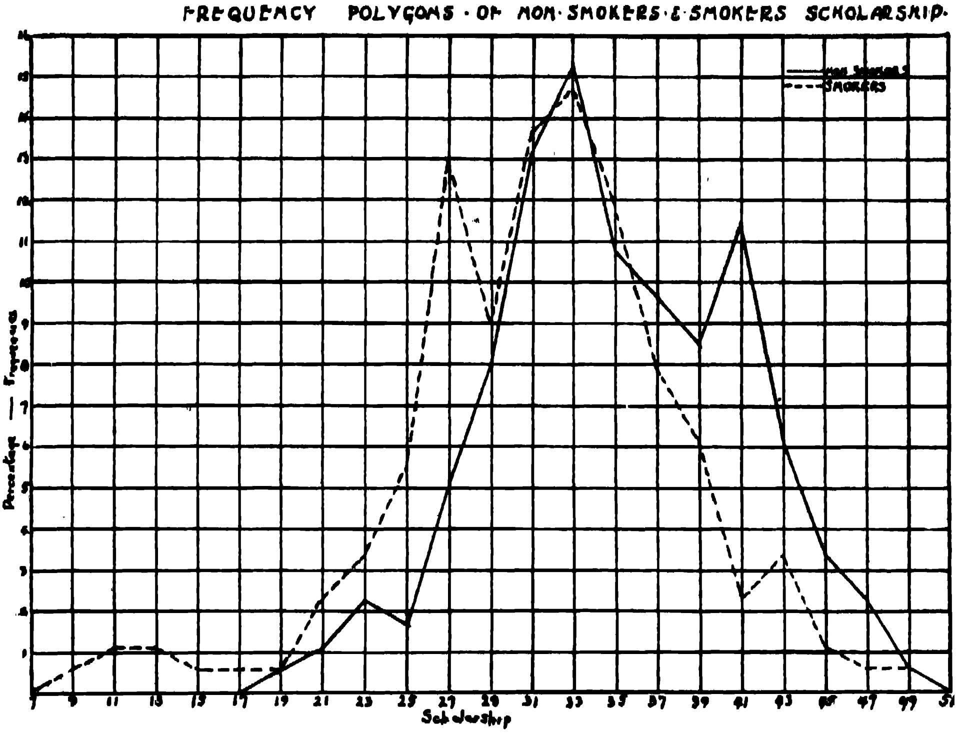


FIG. 1

induces lethargy or that lazy men are the kind that find smoking agreeable. Or again it might happen that smoking is associated with desire for social intercourse and that the gregarious instinct, turning away from solitary study, is the cause of low scholarship. Such speculations are hard to put to scientific proof. If extra-curricular activities are a test of the gregarious instinct then Antioch smokers are not more gregarious than their fellows. We have found a greater proportion of non-smokers than of smokers so occupied. This year, for example, 237 non-smokers engage in 249 extra-curricular activities while 219 smokers engage in 211. But it may well be doubted if this is a fair test.

The problem may be attacked from the other side. Is there any positive evidence that scholarship is decreased by the use of tobacco? Laboratory experiments by C. L. Hull[6] showed some loss in accuracy and in memory by the smokers at the time of smoking. The differences were not so great as to be exceedingly convincing, though the care in controlling the experiments makes them of value. In 1925 the Antioch material appeared also to afford some positive evidence of a causal relationship between tobacco and low scholarship. Among the smokers themselves we found that those who had smoked longest, those who smoked most, and those who inhaled were poorer scholars than the remaining smokers. The differences were not exceedingly significant though they were by no means negligible. This year, however, they do not appear, or if present are so small that they are not statistically valid.

[6] Hull, C. L., *Psychological Review Monograph Series* Whole Number 150, 1924, pp. 1–161.

It is worth noting, as being contrary to some previous observations, that the Antioch abstainers have no advantage in "intelligence" as measured by the Thurstone and O'Rourke tests. In fact both these tests as applied to our 1927 material give a small advantage to the smokers. This is easily explained inasmuch as the great majority of students dismissed from this college because of low scholarship are smokers. Since the smokers lose so many of their least intelligent constituents, the average "intelligence" of the remainder is naturally boosted. It is possible to argue that, but for this process of natural selection, the non-smokers would not only equal but excel the smokers in intelligence. The fact remains that it is not to "intelligence" that we must attribute the superior scholarship of our abstainers now in college.

An interesting possibility that is not very easy to explore lies in the reputed powers of smoking to stimulate or inspire day dreams. It is well known to the psychologists that day dreaming is a refuge of those who find reality too unpleasant. The medical student who can not pass his examinations may enjoy the prestige and emoluments of a specialist by no other way. Can it be that students who have difficulty in adapting themselves to the requirements of intellectual achievement turn by nature to the solace of the weed?

There is still plenty of opportunity for research on this subject. That non-smokers excel in scholarship seems to be indisputable. The reason or reasons for their excellence are still very uncertain.

A HISTORY OF COD LIVER OIL THERAPY

By T. SWANN HARDING

BELTSVILLE, MARYLAND

THE medicinal use of cod liver oil is yet another of our modern ideas which actually reach back into very respectable antiquity for their origins. It constitutes another of those human advances that became obscured, forgotten, actually antagonized, and had later to win its way back to renewed acceptance by hard work. Humanity, like a laggard school boy, actually forgets some of its lessons amazingly easily and is often curiously averse to the process of relearning them.

It is recorded that Pliny and Hippocrates advocated the use of dolphin oil as a remedy for chronic skin eruptions, which shows that fish oil was early used for conditions somewhat similar, perhaps, to those now remedied by cod liver oil. According to "Percival's Essays"[1] cod liver oil had in 1790 long been an invalid food in Scotland and the Isle of Shetland. It was also used at the Manchester Infirmary (England), both internally and externally, to remedy so-called "rheumatism" as early as 1789; at that time this one infirmary was using a hogshead of cod liver oil annually!

In 1807 Bardsley speaks of using cod liver oil effectively on women patients worn out by "rheumatic" attacks (probably due to a depletion of calcium from their bones) after pregnancy. To-day, when we know so many more nice long words, this condition would probably be called "osteomalacia."

A physician named Bennett[2] had actually to revive the use of cod liver oil in 1841, it having fallen into almost complete disrepute. In Holland cod liver oil had long been used specifically for rickets, a disease caused by imperfect deposition of calcium in the bones, and the Utrecht Society of Arts made cod liver oil therapy the subject of a prize essay in 1822. Schenck published the first German article on the use of cod liver oil in 1822.[3] He used it in gout and "rheumatism." But it is 1824 before the record shows the specific use of cod liver oil to cure rickets.[4] It was then used successfully on children of from three to five years of age and soon spread into universal use in Germany.

In 1837, M. Roche communicated to the Société de Médecine de Paris a paper describing the use of cod liver oil in rickets by Dr. Bretonneau. An article of similar import, by one Villard, appeared also in 1836.[5] In each case, be it noted, fishermen had first used the oil empirically on their children and physicians accidentally came upon the matter and gave it wider application.

Now in spite of all this cod liver oil fell into disuse. In the late nineteenth and early twentieth century its specific use to cure rickets had been entirely forgotten. It was often spoken of as a remedy in tuberculosis or even in rickets, but it was regarded merely as a general tonic, easily digested and assimilated, yet not specific. True, no one had ever known that vitamins, and not its rich fat, made it valuable, but it had found specific use in rickets.

For instance, Hare[6] recommended cod liver oil among other "general tonics" and indicated its use, among other

[1] 4 Ed., Vol. II, pg. 360, 1790.

[2] "Treatise on the Oleo Jecoris Aselli," Edinburgh, 1848.

[3] *J. d. Pract. Heilk*, 55, 81, pt. 6.

[4] Shiitte, *Arch. f. Med. Erfahrung*, 79.

[5] Schmidt's *Jahrb.*, 5, 147.

[6] "Practical Therapeutics," Ed. 13, 1909.

things, for rickets. Henoch,[7] a famous children's specialist, at times felt almost convinced of the real value of cod liver oil in rickets but most of the time seriously doubted its efficacy. Rotch,[8] another child specialist, did not even mention cod liver oil in ricket therapy. M. F. Still,[9] yet another, flatly declares that cod liver oil has no specific value in any disease and while other writers on children's diseases casually advised its use[10] it was not much used.

From 1908 to 1912 a prominent German investigator named Schabad sought very hard, against considerable acrimonious opposition, to prove that cod liver oil, unlike other oils, was of specific value in the treatment of rickets. In 1910 cod liver oil therapy was spoken of as struggling to overcome scientific skepticism, but it was added that pharmacologists and physicians generally distrusted its specific value.[11] As late as 1913 a French research worker[12] "proved" that the therapeutic action of cod liver oil depended upon the fact that it increased the bodily utilization of protein.

It was actually in 1916 that the celebrated Polish investigator who was a pioneer on vitamins, Casimir Funk, suggested tentatively that vitamins might be accountable for the efficacy of cod liver oil in promoting normal bone growth. Then Dr. Alan Brown and coworkers[13] in 1920 found that the administration of cod liver oil to rachitic children definitely increased the calcium content of their blood. Then came E. V. McCollum.

[7] "Lectures on Children's Diseases," 1889.

[8] *Pediatrics*, Philadelphia and London, 1901.

[9] "Common Diseases of Childhood," London, 1912.

[10] Meiggs, Pepper, 1886; Starr, 1894; Holt, 1896; Kerley, 1907; Fischer, 1907.

[11] Rosenstern, *Berl. Klin. Wochenschr.*, 47, 822.

[12] Maignon, *Comp. Rend. Soc. Biol.*, 72, 1054.

[13] *American Journal Diseases of Children*, 19, 413.

Until now other substances had been known to be useful in rickets, but none seemed so efficacious as cod liver oil. Actually two vitamins were involved where only one was assumed to be present; these two are called fat soluble A and D. McCollum began to publish a stream of articles on vitamin therapy, describing the use of cod liver oil in the prevention of rickets in 1921.[14] He first produced experimental rickets in animals and then cured it by the administration of cod liver oil.

He became suspicious that cod liver oil differed basically from such things as butter fat because, while both demonstrably contained large amounts of vitamin A, which controls growth, the former cured rickets and the latter would not. He finally announced that rickets prevention was accomplished by the second fat soluble vitamin, which he called D. Thus spinach is very high in A and lacks D; butter fat is high in A and low in D; cod liver oil is high in both. Therefore the latter alone, of these foods, can both cause normal growth and prevent rickets.

A lack of vitamin A, besides stunting growth, also causes susceptibility to eye, ear, sinus and lung infections; a lack of D causes rickets. But to prevent rickets properly calcium and phosphorus must both also be in the food in correct proportion to each other for easy bone building by the body. They occur so in milk. Milk, however, is low in vitamins. Its vitamin content is perhaps more important than its butter fat content, now used as a standard of value. Milk will become very potent in vitamin D, as will many other foods, if irradiated with (exposed to through a quartz but *not* a glass plate) ultra-violet light. It may also be rendered higher in vitamins A and D by proper feeding of the cow on fresh greens and its exposure to sun

[14] *The Journal of Biological Chemistry*, 45, 333–348.

or to ultra-violet light. Or it may be used for its minerals and the vitamin deficiency made up with cod liver oil.

After McCollum things happened rapidly. In 1923 it was shown[15] that the calcium of the blood varies very little from animal to animal of the same species. Eating calcium salts or their injection will at most cause but a temporary rise in blood calcium. But there is a chronically low blood phosphate in rickets and in some cases of kidney trouble. Various diets were fed, deficient in calcium or in phosphorus, and rickets always developed, but it could readily be cured by cod liver oil, and it was observed that in such cases the blood calcium also rose to normal.

In 1924 *The Journal of the American Medical Association*[16] made this statement editorially:

> It is an extraordinary circumstance, as was recently remarked, that a substance containing neither calcium nor phosphorus when administered to an animal whose blood is deficient in these elements should have the power to cause the calcium or the phosphorus, as the case may be, to rise to, or nearly to, the level commonly regarded as normal and thereby to establish the normal equilibrium. Furthermore, the cod liver oil not only acts as a regulator of the calcium and phosphorus metabolism (use by the body), but also permits the organism to operate with greatly increased economy. In the presence of calcium or phosphorus starvation cod liver oil enables the animal to get along as if the calcium or the phosphorus were supplied in sufficient or almost sufficient quantity in the diet. It is necessary to suppose that cod liver oil brings about maximal utilization of the minimal quantity of calcium or phosphorus in the diet. It greatly reduces waste of these elements and, therefore, must bring about a maximal absorption from the alimentary tract.

This is the case for cod liver oil therapy stated authoritatively but in simple language.

The statement does not stand altogether unchallenged because certain workers[17] claim that the addition of cod liver oil to a diet really deficient in calcium will not raise the percentage of calcium in an animal's body. They declare that some salt of calcium, like calcium lactate, must be fed to accomplish this. But vitamin D does control the successful utilization of calcium by the body.

Cod liver oil retains this efficacy remarkably. It may be stored many months and still remain potent.[18] Furthermore, feeding cod liver oil or irradiating with ultra-violet light will increase the number of eggs chickens lay and will also increase their hatchability.[19] This is directly related to the amount of calcium in the body of the chicken embryo, it being increased when light and cod liver oil are used.

When giving milk, cows and goats tend to lose large amounts of calcium from their bodies because the milk contains so much. This loss may be prevented in goats by exposing the animals to ultra-violet light for a few minutes daily.[20] Sunlight seems thus more important to the animal than green plant food. It would seem that cod liver oil might also be useful here, but when cows were fed cod liver oil they did not respond as they did to light, but continued to lose calcium during lactation.[21]

It was observed above that the vitamins in milk may be increased by properly feeding the cow. English investigators have worked on this. At first they had the two vitamins A and D mixed up, as every one else did. But ultimately they showed that the amount

[15] Park, E. A., Guy, Ruth A., Powers, G. F., *American Journal Diseases of Children*, August, 1923, 26, 103.

[16] Vol. 83, pg. 1169.

[17] Sherman and McLeod, *J. Biol. Chem.*, lxiv, 429, 1925.

[18] Hart, Steenbock, Lepkovsky, *J. Biol. Chem.*, lxv, 1925, pg. 571.

[19] Hart *et al*, *Jour. Biol. Chem.*, lxv, 579, 1925.

[20] Hart *et al*, *Jour. Biol. Chem.*, LXII, 117, 1924.

[21] Meigs *et al*, *J. Agricultural Research*, 32, 833.

of vitamin A in milk depends on the cow's food and is unrelated to its exposure to light, while the amount of vitamin D depends upon whether the animal is or is not exposed to sunlight. As a whole, then, a cow on green pasturage will give the best milk from the vitamin standpoint.[22]

The application of this idea to a nursing woman followed not long after.[23] It was shown that if a nursing woman were exposed to ultra-violet light for a few minutes daily her milk became very potent in the rickets-preventing vitamin. While the milk would not cure rickets in rats when the woman was not exposed to the light, it cured the rickets readily when she was exposed.

Vitamin D, which occurs in cod liver oil, can, it seems, be produced from certain fats by their exposure to light. There is a human fat named "cholesterol" which occurs widely distributed near the skin. It has been shown that if this fat is exposed to ultra-violet light, or to sunlight, some of it is transformed into vitamin D by that exposure.[24]

This exposure does not take long. In fact it must not take too long. If it is permitted to go beyond a certain point the vitamin D is destroyed again. Cholesterol normally contains no vitamin D whatever; it will not cure rickets. But expose it to the ultra-violet rays from a mercury vapor lamp for one hour at a distance of eighteen inches and five per cent. of it will become a crude oil which is extremely high in vitamin D, protective against rickets; the rest of the cholesterol will still contain no vitamin D. More recently it has been held that absolutely pure cholesterol will not produce vitamin D and that some impurity is involved,[25] but the fact remains that vitamin D is produced by exposure to light and it has even been shown that the Coolidge high voltage cathode rays (so widely bespoken in the press a short while ago) will activate cholesterol in a similar manner. But exposure of an experimental animal to these rays is not a success because the animal can not stand such rigorous treatment and remain alive.

This brief outline of the history of cod liver oil therapy has demonstrated that the substance was given medicinally quite a long while ago as a specific for rickets, but that this use was forgotten and the oil remained merely one of the general tonics to be used empirically for debilities of all sorts. Later it fought its way back to recognition as a specific for rickets. Speculation began as to the reason for its potency and, after a period of crediting its nourishing qualities, it began to be supposed that the oil contained vitamins. Ultimately this hypothesis proved correct and it was found that ultra-violet light would impart similar properties to other oils and fats which were normally quite inert from the vitamin standpoint. To-day ultra-violet irradiation and cod liver oil are both used to cure rickets, but the latter is recognized as more effective and is firmly established as a specific therapeutic agent.

[22] Luce, *Biochem. Jour.*, 18, 716, 1229; 1924: Chick, Roscoe, Luce, *Biochem. Jour.*, 20, 632, 1926.

[23] Hess, Weinstock, Sherman, *Jour. Amer. Med. Assoc.*, 8824, January 1, 1927.

[24] Rosenheim and Webster, *Biochem. Jour.*, 29, 537, 1926; Hess and Shear, Kramer and Shelling, *Jour. Biol. Chem.*, 71, 127, 213, 221, 1926.

[25] Hess, *Proc. Soc. Exp. Biol. and Med.*, 24, 369, 1927.

A HISTORICAL SKETCH OF THE RELATIONSHIP BETWEEN HISTORY AND SCIENCE

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THE relations between history and science seem not to have been hitherto at all close. It is true that the Greek word, historia, might indicate any investigation of the past, of the present or of nature, and that this usage persisted into the middle ages when in Latin anatomical manuscripts of the twelfth and thirteenth centuries one finds a "history of incisions," a "history of arteries," a "history of muscles" and a "history of nerves." It is true that before the present age of specialization a single person was more likely to deal with several fields of knowledge or research. But the number of those whom we know to have been productive in both history and science is not very impressive, partly perhaps because their writings in the one field or the other have been lost. Those who have engaged in both the historical and scientific fields of activity have often kept them in separate compartments rather than effected a happy union between them, and have not necessarily been led either to a historical view of science or a scientific method in history. Calendars have developed into fasti and annals, and chronologists have often been men of some mathematical or astronomical attainments. The same writers were apt to retail historical anecdotes and yarns concerning animals and other marvels of nature: witness Aelian of Praeneste and the Deipnosophists of Athenaeus. Encyclopedists comprised the phenomena of nature and the story of man along with everything else in their loose collections. But such associations are not very impressive. When scientific matter has been introduced into a history in the past, it has usually been in the nature of a digression.

Dr. Sarton begins the first volume of his recent monumental "Introduction to the History of Science" with Homer, but as my time is somewhat limited, I will pass on immediately to Herodotus, once regarded as the father of history. His epic or dramatic variety of history, largely personal in his first book, in the following survey of the lands of the Near East strews before us a number of valuable bits of scientific or pseudo-scientific lore. But it may be questioned if the Ionian philosophers with their world grounds and evolutionary theories, their scientific curiosity concerning the past, did not approach closer to a true combination of history and science than either he or Thucydides, whose critical and sophistical treatment brought history into closer relation to the theoretical science of the day. And this raises the query whether history shall appeal primarily to the human interest motive, as in Herodotus, or be limited largely to past or even recent politics, as in Thucydides and so much recent American teaching of it, or whether it shall survey the entire past with a scientific purpose and method and with especial emphasis upon the past of those intellectual faculties and that mental life which distinguish man from other living beings and from other objects of scientific investigation.

The ancient Greek who best combined the historical and scientific interests appears to have been Aristotle. It is true that the notion which he handed on

of science as concerned only with eternal and unchanging truth leaves little room for history. But he wrote a History of Animals, a Constitutional History of Athens, and treated of both the development of Greek literature and the views of philosophers before him. His medieval and early modern influence, however, was far more as a philosopher and a natural scientist than as a historian.

In the Hellenistic period which followed Aristotle, the bookish compilation in libraries of histories from previous histories became largely disassociated from the study of anatomy, astronomy, botany, physiology, and the like; which, while also too inclined to repeat past authors' opinions, seem to have maintained more contact with reality.

With Pliny the Elder, however, in the Roman Empire we come to a man who in his Historia Naturalis dealt with science for the most part historically. While he can not be said to have dealt with the past scientifically, he is none the less after Aristotle our outstanding example in antiquity of the union of history and science; and he was until then and for long to come the chief historian of civilization. His vast influence in medieval and early modern times was in the main conservative, anchoring science to previous lore and attaching the ball and chain of past superstition to the winged ankles of Mercury.

The Bible is stronger on its historical than its scientific side, and the same was naturally true of early Christian thought and writing. History was now reviewed and reconstructed as the working out of a divine plan and purpose, but while we have a sort of Christian Pliny in the encyclopedist and chronologist, Julius Africanus, and while such works as the Hexaemeron of Basil cater to an obvious curiosity concerning nature, this apparently existed in the audience more than in the preacher. Christianity has often been called a great historical religion, but until Mrs. Eddy it was seldom accused of being a great scientific religion. The Schoolmen and medieval theologians nevertheless attempted with the aid of Aristotle to make it such, and to correlate and reconcile Trinity with First Cause, angels with spheres, miracle with natural law and marvel, and, in general, traditional supernaturalism with a rational theory of the universe. The effort to establish this bold synthesis for centuries absorbed many of the most advanced thinkers of the medieval universities, but was already in the fourteenth century questioned by some of the ablest minds among them, was later attacked by humanists and religious reformers, and finally was generally abandoned by an indolent and dilettante early modern society. The study and writing of history at no time had much relation to it, except that the stress laid upon authorities reminds one of historical method. But we must turn back again to the earlier Moslem world.

The wide sweep of Arabian conquest, embracing three continents and joining such distant lands as Spain and Persia in the communion of the same language, promoted a cosmopolitanism and internationalism favorable to the development of history and science side by side. Despite nomadism and fanaticism, travel and study gave breadth of view and insight. It is true that we can no longer regard the Arabic speaking and writing world as the sole channel by which an interest in science flowed first to the later medieval, and then, augmented by a supposed revival of classical science, to the modern world. We now realize that there was always some interest in science during the early middle ages both in the Byzantine Empire and the Latin West, and that the renaissance of the twelfth and thirteenth centuries, far more important scientifically than the later so-called classical Renaissance, was not due merely to translations from the Arabic. At the same time there was much more scientific writing done in Arabic than in any other language from the seventh to the eleventh century.

This Arabic science, like so much of ancient, medieval and early modern science, was mingled with superstition and magic, but was also often marked by rational skepticism and experimental method. It appears to have had much greater effect upon the West than did the Arabic historiography. But for the combination in an Arabic writer of the interest in history and science with a rational attitude one may refer the English reader to the works of Albiruni on India and the Chronology of Ancient Nations, both available in translation.

We have just referred to superstition and magic. The pseudo-science of astrology, whose origins have not yet been satisfactorily established but which at least existed in a highly developed form by the Hellenistic and Roman periods, was still further elaborated by writers in Arabic such as Albumasar, and continued upon the same basis into late medieval and early modern times in the West, while it of course still affects all Oriental peoples. Astrology had important relations both to history and to science. Not only were all properties of plants, stones and animals referred to the planets and signs, and the formation and medical treatment of the human body placed likewise under their influence, but we also find the astrological interpretation of history as in the treatise of Alkindi, "the first and only great philosopher of the Arab race," on the duration of the Arabian Empire, or in the theory of great conjunctions of the superior planets as marking transitions and periods in history. Comets and eclipses, too, were no mere natural phenomena but related to the course of human history. Rulers assiduously consulted astrologers; it was important to know the particular constellations under whose influence a given region lay; the date of the founding of a city was as significant as the horoscope of an individual; and annually, at least in fifteenth century Italy, elaborate forecasts of the probable course of events—natural, social, and political—during the coming year or for each of its four seasons, were issued not by half-educated impostors but by university professors. Never in all probability have history and science been in such close relationship as they were supposed to be brought by astrology.

One reason why Arabic historiography made less impression on the West than Arabic science may be that already in the tenth and eleventh centuries there were several remarkable historians in the Latin world with whom Gerbert can alone be compared in the realm of Latin science, and he, by virtue of his informing letters, was a bit of a historian too. Since the medieval Latin revival of learning in the twelfth and thirteenth centuries there has been a continuous development of science to the present time. In the fourteenth century we have significant criticism and amendment of the Aristotelian physics; in the fourteenth and fifteenth centuries much activity in medicine and astronomy, experimental method in anatomy and surgery. Science to-day would not stand so firm if it did not have these deep foundations. This scientific development seems by and large to have been only slightly affected one way or the other by such historical movements as the so-called Italian Renaissance or humanism, and the Protestant and Catholic Reformations.

The historical writing of the time was more susceptible to their influence. The humanists, who took rather more interest in history than in science, understood classical history and writers better than most of their medieval predecessors had, but this did not necessarily make them better historians or scientists. They were too prone to imitate Livy, to take some such barren subject as The Carthaginian Domination of Spain before the Punic Wars. And they ceased to understand the middle ages. Not all historians of the fifteenth and sixteenth centuries were humanists fortunately, but the disparagement of the medieval period became general and has been

usually retained by men of science to this day. A well-balanced estimate of the past was further rendered difficult by the partisanship of Catholic and Protestant historical writers. Their researches, it is true, led them back to the medieval as well as to the early Christian period, but had the regrettable outcome that medieval history was long regarded as a field practically identical with church history.

Meanwhile, however, literary and archeological erudition and textual criticism, aided by the invention of printing, had been making steady strides forward and led to the gradual formulation of something approaching scientific method in historical investigation. Greater toleration and freedom from religious bias also came as a reaction from the Reformation and Wars of Religion. In the course of the seventeenth and eighteenth centuries both history and science also abandoned the astrological point of view. But the Biblical account of pre-Greek history still held the field practically unchallenged in the skeptical eighteenth century of the French Encyclopédie and Voltaire. Sir Isaac Newton, for example, was a very sorry historian who tried to fit ancient history to the Procrustean bed of Biblical chronology. Some of the great German philosophers of the eighteenth and early nineteenth century engaged in scientific investigation of a sort, and they almost all had their philosophies of history, but I do not know that there was much connection between these two activities.

But in the meantime the progress of erudition had given rise to histories of learning, of the universities which reached back into the middle ages, and to collections of Scriptores. There was almost a craze for writing the biographies and bibliographies of all the illustrious men, and especially the writers, who had been connected with a given city or religious order or university. These histories were much alike and used the works of their predecessors a great deal, but at least they contain materials or suggestions for the history of science. I mention them for the further reason, however, that historians to-day may be in danger of continuing somewhat the same bookish scholasticism. To a considerable extent historical scholarship of the nineteenth and twentieth centuries has simply followed along and broadened out paths that were laid down in the sixteenth, seventeenth and eighteenth centuries. The much vaunted Monumenta Germaniae Historica are after all but a more critical and greatly enlarged sequel to many such preceding efforts: Chevalier is only a digest of the kind of works just mentioned.

Much of this is of course inevitable. Yet if the historian is to arrive at results at all comparable to those of the scientists, he must be original and fertile in his mode of approach, not merely accurate and faithful. Has history yet had its Galileo or Harvey or Newton or Linnaeus or Darwin or Einstein? On the other hand, it must be confessed that the great advance of science has been due even more to the invention of mechanical aids such as the mariner's compass, the barometer, the accurate time piece, the microscope and the telescope, photography, than to the ideas of such individuals. Can history hope for the devisal of such facilitations in method, each opening a whole new world as it were or side of human life to the examining eye? Archeological discovery of the past century and recent years may be said to have had such an effect, extending our vista as far back in time as the telescope has carried it on into space, and to have appealed almost alike to historians and to men of science. Geology and biology alone would hardly have carried the day for evolution without it. Advocates of the New History believe that recent science and thought offer other instruments which may prove almost equally efficacious in extending, correcting, or substantiating our previous knowledge and evaluation of the human past.

THE GASTRONOMY OF COLONEL CARTER OF CARTERSVILLE

By Dr. J. HOWARD BEARD

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MUCH of the social, political and intellectual life of the people clustered about the banquets of Babylon, the festivals of Greece, the feasts of Rome and the coffee houses of England, but all these lacked the wholesomeness, the hospitality and the charm of a dinner of a Virginia manor in those happy days often designated as "befo' de wah." Belshazzar's table had luster, Epicurus gave eating fastidiousness, Lucullus prided himself upon the costliness of his cuisine, and Boswell learned his Johnson in the taverns of London, but only a Colonel Carter of Cartersville could make a dining room so inviting and the food so physiologically exact that the guests "wanted life made up of one long dinner continuously served."

If correct eating is the realization of an indefinable satisfaction and is the procurement of adequate nutrition through the gratification of the appetite, their attainment depends not only upon the combining of pleasure with the routine of bodily nourishment, but upon the wise choice of food, finesse in its preparation, the attractiveness of its serving and the creation of an atmosphere psychologically proper to stimulate functions essential to normal digestion. In each of these fields, Colonel Carter was a connoisseur without a peer.

The colonel was a native of Fairfax County and of one of the "vehy fust families of Virginia." He was frank, generous, tender-hearted and as simple as genuine. He had a soft, low voice, tempered with a most attractive cadence. He possessed a fair education and considerable knowledge of men and of the world. "He was proud of his ancestry, of his state and of himself. To share with you his last crust was a part of his religion; to eat alone, a crime."

He had more than the genius of an epicure, he had inherited the instinct to dine well. To him a good dinner was the necessary preliminary to all the important duties of life—the pièce de résistance of social intercourse. The head of his table was his throne. There he ruled supreme with a splendor and a charm that reflected the varied hues of the many sides of his delightful nature. It is not surprising that such a host should portray in his dinners the commingling of the exactness of science, the emotions of an artist, the chivalry of a knight and the cordiality of a Southern gentleman of the old school.

Although the colonel fell upon evil days financially following the Civil War, it did not dull his keen appreciation of the relation of attractive surroundings to eating and digestion. He, accordingly, selected the finish and the furniture of his dining room to focus the stimulating effect of a delightful environment upon the dining table.

The room presented a charming interior, and a remarkable appearance of coziness and restfulness. An open fireplace added its cheerfulness, while an English grate set into the chimney offered convenient facilities for the production of the brews and mixtures for which the colonel was justly famous. An unpretentious sideboard, some easy chairs, a pair of silver candelabra on the mantel and a few borrowed etchings and sketches made the table, which occupied

the center of the room midway between the fireplace and the grate, the one object to fix the attention.

It was covered with a snow-white cloth resplendent in old India blue which matched the plates warming by the hearth. In its center was a great dish of white crisp celery and at either end a pair of coasters—one holding a cut-glass decanter of Madeira; the other, awaiting its customary bottle of claret.

In these modest surroundings, Colonel Carter, by his knowledge of food, the warmth of his hospitality and by his extraordinary personality, converted a meal into the classic of a Virginia dinner, putting into practice gastronomical principles which anticipated certain discoveries of modern science by several decades.

The colonel promoted the hygiene of nutrition by the regularity of his meals and by his insistence upon the punctuality of his guests. To be ten minutes late to dinner was almost unpardonable, because a duck could not be cooked "a minute over eighteen" and "the burning of a canvasback was a crime." To him all food had its exact minute of cooking and precise temperature for serving. Such scientific accuracy excluded dilatory diners.

He gave prestige and social correctness to his dinners by always dressing especially for them. Chad, the waiter, emulated the example of his master and appeared brilliant in white jacket and apron. He took his position behind the colonel's chair and with great dignity announced that dinner was served.

The colonel immediately said the blessing—"an old custom of my ancestors which I never omit." Dinner was an occasion of fellowship and vivacity; business was adjourned—"not a word befo' " the meal was finished.

Worry and haste, the twin brothers of dyspepsia, never passed the threshold of his dining room. Its arrangement and his companionship immediately gave his guests comfortable relaxed bodies, free and easy minds and cheerful happy spirits. Nothing, not even an impending duel, could impair his appetite or dull the colonel's enjoyment at dinner.

"Throughout the entire repast he was in his gayest mood, brimming over with anecdotes and personal reminiscences, and full of rose-colored plans for the future." His conversation would range from the preparation of pickles to politics; from family blood to 'possum hunts; from domestic delicacies to modern literature. His talk was as delightful as potent in the production of an excellent mental attitude for normal digestion.

Lest some sorrow or disappointment hidden behind the smiling countenance of a guest should suddenly emerge to mar the joy of dinner, the genial colonel would admonish his hearers: "Salt yo' food, suh, with humor. Season it with wit, and sprinkle it all over with the charm of good fellowship, but never poison it with the cares of yo' life. It is an insult to your digestion, besides bein', suh, a mark of bad breedin'."

No fiat of preventive medicine needs more an Elijah and a modern Carmel from which he might proclaim it than: care, speed and food-bolting wreck health. More and more is the meal time being robbed of its restfulness, its cheerfulness and charm, by becoming a business conference and the zero hour for launching drives. How futilely does the busy man of to-day sacrifice pleasure, mastication and time for eating—the essential of normal digestion—only to find that he can not escape the consequences of his folly by swallowing pills, potions and powders.

Unwittingly, Colonel Carter seems to have employed every physiological method to accelerate and to intensify the appetite through an appeal both to the psyche and to the sensorium. By subtle suggestion through his delicate cautions to Chad, his cook, in the pres-

ence of his guests, he used their eyes and ears to convey powerful psychological stimuli to create the desire for food and to produce conditions favorable to digestion.

An excellent example of his methods, though unconsciously performed, to prepare the minds of his guests for dinner, is well illustrated in his directions for the cooking and serving of canvasback duck.

"Not a minute over eighteen, Chad. . . . Lay 'em here [head of table], Chad —right under my nose. Now hand me the pile of plates sizzling hot and give me the carving knife a turn or two across the hearth."

(To one of the guests) "Major, see the blood, suh, follow the knife."

Chad: "Suit yo', Marsa?"

Colonel: "To a turn, Chad."

Like an artist mixing his pigments to give his portrait the right effect in high lights, gradations and shadows, the colonel compounded sweet, sour, salt and bitter with a master's skill to produce an exquisite taste. "A drop of sherry," "a dash of bitters," "the juice of a lemon," "a pinch of salt," "a dust of cayenne" and "smothered in sweets" were used to prepare the palate for the kind of food "they raise, gentlemen, down my way."

Food fit for a dinner at the colonel's must not only have a delicious taste and "send a savoury cloud of incense to the ceiling," but each article to be palatable must be cooked to the minute—neither more nor less—and even the temperature of the claret was "lovingly tested by the palms of the hands."

As a landscape painter in picturing a scene looks beyond his canvas to the myriad-tinted woodland, the meadow with its meandering stream and to the sunset glow, so the colonel in preparing a dinner saw his ducks diving for wild celery in the bleakness of winter and his venison feeding upon sugar maple. Artist-like he put his vision of nature into his masterpiece—a Virginia dinner.

"There, Major," said the colonel, as Chad laid the smoking plate before me, "is the breast of a bird that fo' days ago was divin' for wild celery within fo'ty miles of Carter Hall."

"No jelly, Colonel?" said Fitz.

"Jelly? No, suh, not a suspicion of it. A pinch of salt, a dust of cayenne, then shut yo' eyes and mouth and don't open them 'cept for a drop of good red wine. It is the salt marsh in the early mornin' you are tastin', suh—not molasses candy."

"But you use it on venison?" argued Fitz.

"Venison is different, suh. That game lives on moose buds, the soft inner bark of the sugar maple and the tufts of sweet grass. There is propriety and justice in his endin' his days smothered in sweets. But the wild duck, suh, is bawn of the salt ice, braves the storm and lives a life of peril and hardship. You do not degrade a' oyster, a soft shell crab or a clam with confectionery; why a canvasback duck?"

Whether it was in serving diamond-back terrapin, so famous in the early banquets of Maryland and Virginia; the canvasback duck, the most delicious of wild fowl; venison, clam or oyster; the fundamental principles of the colonel's epicureanism are clearest when presented in the words of the inimitable Chad, "You got to know 'em fust to eat 'em." To prepare food without proper consideration of its source and characteristics in its native state was "scand'lous." To season it incorrectly or to dress it in inappropriate trimmings was likely to be followed by dire consequences, as certified by both the master and his cook.

In a protest against the use of jelly on duck, the colonel remarks disapprovingly, "You Nawtherners don't really treat a canvasback with any degree of respect. You ought never to come into his presence when he lies in state without takin' off yo' hats. That may be one

reason why he skips over the Nawthern States when he takes his annual fall outin'."

Chad was almost as hopelessly epicurean as his master and was equally as sensitive to unsuitable preparation of food. "Tar'pin jes like crab, Major," said Chad, dropping a spoonful of butter, the juice of a lemon and a pinch of salt into the impromptu dish (shell). "Now, Major, take yo' fork and pick out all dat black meat an' dip it into the sauce an' wid ebery mou'ful take one o' dem little yellow eggs. Dat's de way to eat tarpin. Dis yer stewin' him up in pote wine is scand'lous. Can't taste nuffin but de wine. But dat's tar'pin."

Dinner, in accordance with convention, began with soup—not an insipid, mock concoction vaguely suggestive of something or other—but soup, capable of whetting the appetite and starting the digestive juices. It was served hot in a covered tureen which was placed in front of the colonel. When the lid was removed it sent "a savoury cloud of incense to the ceiling," which caused the tongues of the guests to tingle as they awaited its ladling and serving with suppressed impatience.

Following the soup, there was boiled fish fringed by slices of hard boiled eggs and "ovaled by a hedge of parsley and supplemented by a pyramid of potatoes with their jackets as ragged as tramps. Then a ham, brown and crisp, and bristling all over with cloves." Finally, the canvasback ducks, cooked to the exactness of the minute and to the precision of a turn. These, the crisp white celery, the usual accessories, the Madeira and claret in the coasters, and dinner was completed except for a pipe of "Virginia tobacco, suh—raised at Cartersville—cured by own servants. . . . Every breath of it is a nosegay."

At the end of the war, Colonel Carter was able to keep Carter Hall in his family, only by mortgaging half of his estate to his aunt. He went to New York in the hope of recouping his fortune and of returning to restore his ancestral home to some of the grandeur that once made it the center of the life of Cartersville. It was during his sojourn in the north that the dinners were given that made this chevalier of Virginia a celebrity in the domain of gastronomy. These repasts were mere reflections—miniatures of those when Carter Hall was in flower.

The belief that coal might be found on the manor at Cartersville suddenly one evening brought the colonel, engineers, financiers and Chad to Carter Hall. Next morning Aunt Nancy served a true southern breakfast for the guests in the dining room permeated with the fragrance of roses and on a table sprinkled with them. "Such a breakfast! The outpourings of a Virginia kitchen, with the table showered with roses and the great urn singing and smoking, and the relays of waffles and cornbread and broiled chicken; all in the old-fashioned dining room with its high wainscoting, spindle-legged sideboards, and deep window seats; the long moon-faced clock in the corner and the rest of it. After that the quiet smoke under the vine-covered portico with the view towards Cartersville."

In the setting of this breakfast is also to be found the beauty, the romance, the hospitality and the abundance—the elements of the gastronomy of her nephew. The day begun so propitiously, ended even more so. Coal was discovered—"a bed of bituminous, clear down to China."

Colonel Carter was now wealthy beyond his brightest anticipation. Carter Hall was to be restored to some of its pristine glory as the center of the life of Cartersville. He was to ascend again his throne at the head of his table amid the beauty and fragrance of roses to reign as the most hospitable of hosts, as a gastronomist incomparable and as the connoisseur of food par excellence.

PSYCHOLOGY AND MANAGEMENT

By Professor FRANK T. CARLTON
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MEN in all walks of life have a sharp hunger for approval and a corresponding distaste for whatever tends toward scorn, ridicule or inferiority. Each human being craves a recognition of his own individuality. The consciousness of power is sweet to the great majority. Some like the pomp and publicity which accompanies the exercise of authority; others are willing to be "the power behind the throne"—to be the invisible government. The captains of industry and labor leaders have usually been self-assertive men. Publicity, "the thrill of prestige and fame," possesses great attractions for all except a few choice souls. Men in subordinate positions, in the great drab rank and file, compensate for their lack of power and prestige by swaggering and boasting. Speeders, pace-setters and fast men gloat over their fellow-workers. If the chance of beating one's competitor is excellent, rivalry spurs one to make an additional effort. Prizes, publicity in the company paper, ratings and the like stimulate wage workers—and others. Industrial democracy, like political democracy, possesses an appeal to the instinct of self-assertion.

The small boy likes to boast of his own strength and achievements, and of the courage of his father. Mature men who have achieved little of success are prone to allude to their prowess in the past. Man, no matter what his station in life may be, loves to recount to an admiring group his remarkable achievements during the day. We love inequality and privilege provided the cards are stacked in our favor. The fraternal organization with its Grand High Potentate and its lesser lights, caters to this instinct. The desire to get one's name in the paper is by no means uncommon. Much of the popularity of games such as football, grows directly out of the popularity and publicity gained by the players. Certain varieties of "conspicuous consumption" are indulged in chiefly to indicate the spending capacity and, hence, the income and presumably the worth of the spender or of the spender's family. The idler and the worker, the professional man and the mechanic, the rich and the poor, and the young and the old, are in varying degrees affected by this primal impulse. Content and zest in industry go out of the door when little or no opportunity is offered for the nourishment of this impulse.

On the other hand, no one likes to be classified as a cog, a number or a commodity. To be treated as insignificant is distasteful. To feel that one is of little consequence and near to the "zero of insignificance," runs directly counter to deep-seated and persistent impulses and instincts. It is especially pleasing to have others recognize our importance and significance. Forces which develop within the worker a feeling that he is being belittled or degraded make for unrest and suspicion. One of the potent reasons for opposition to the introduction of machinery and more recently to the development of scientific management programs, has been the more or less conscious feeling that in some way these innovations tended to degrade the worker by taking away his craftsmanship.

Large-scale industry, great population centers, extreme subdivision of labor, emphasis upon scientific procedure, and the tendency toward impersonal relations in industry have introduced certain difficult problems into modern industrialism. New methods of doing the job and new working and living environments

are developing within the ranks of wage earners certain stresses and strains which bid fair to make the workers feel that the individual is of little consequence, that the worker is only an insignificant part in a machine beyond his control and understanding.

In the next decade, industrial peace and productiveness will depend upon the application of the principles of industrial psychology. Human engineering rather than mechanical engineering, is to be the potent factor in industrial advance. Man is a bundle of conscious and unconscious impulses or instincts which must be reckoned with. Industrial methods often needlessly and heedlessly run counter to deep-seated, inherited, and not easily changed, instincts. A major problem of industry is to make conditions square as far as possible with human nature. In these days of education for all and of universal suffrage, all movements which tend to depress the great rank and file and to put its members in positions of irresponsibility, and loudly to proclaim the superiority of management and the investor group, tend to drive the masses into a cohesive group likely to take drastic and revolutionary action when appealed to by certain types of leadership.

In our modern industrial civilization, four potent forces may readily be discovered tending to make the individual feel insignificant. 1. Modern industrial life is dominated by machine technology. The machine standardizes and mechanizes the forms of human association. The development of large-scale and standardized industry introduced the impersonal element into business relations. It became easy for the management out of touch with the men, to look upon the worker and the machine he tended as being similar. The dignity and skill of the craftsman seemed to be lost in the strange atmosphere of the large shop; the worker felt that he was being transformed into a machine tender. The machine set the pace; the "iron man" appeared to dominate over flesh and blood. As a consequence, the worker began to feel resentful when known as a number or a cog. Under such conditions, a tactless foreman or higher-up boss may give orders in such a fashion that the worker is aggrieved. Many foremen and managers of the type believing in "driving" the workers under their supervision, feel that it is necessary to belittle the worker and the importance of his work in order to keep him "in his place." Again, a type of management is found in many large plants which ignores the individual and thinks of workers only in the mass. Under such conditions, the employee begins to nurse grievances, fancied or real; he becomes a stickler for his "rights." "Wrong behavior patterns" result.

Scientific management tends to "depersonalize orders"; the situation determines what orders must be given and obeyed. However, unless the reasons for "depersonalized orders" are made clear to the workers or their representatives, they will continue to resent incidents of the new order of things. Education of the worker and publicity as to the affairs of the company are essential to the satisfaction of the order receivers. The workers feel that the joy and pride in work has been stolen from them by the advent of the machine, scientific management and standardization. They demand that the thrill of craftsmanship and of individual worth be restored. Truly, the over-organization, the de-humanizing, of industry is on trial. If industry is organized so that the rank and file of workers are made to feel that they constitute cogs in a social machine, that they are a nondescript group of inferiors, they will find sooner or later a way to emphasize their importance. If men are working for themselves or if they clearly see certain advantages, they are willing to subject themselves to a considerable degree of routine, regularity and machine tending; but they rebel against

being made semi-automatons for the benefit of others.

There are interesting exceptions to the statement that machinery and large-scale production tend to make the worker feel that he counts for little. The locomotive engineer is recognized as holding a position of greater dignity and importance than the driver of the ox-cart. The operator of a gigantic traveling crane is looked upon as being far superior to the man with the old-fashioned wheelbarrow. With these and other illustrations in mind, may it not be asserted that our problem in regard to machine technology is due in part to the fact that many processes which are routine and monotonous have not as yet come under the sway of the machine? When a process becomes routine and the performer becomes almost an automaton, that process may readily become a job for a machine; but a way must be found to pass on to the workers a considerable portion of the benefits of increased production due to the introduction of new machinery.

2. As a consumer of the output of large-scale industry, the individual must take a standardized product at a fixed price. There is little or no catering to individual idiosyncrasies or individual bargaining. One of the famous Ford cars has been exactly like another; its price has been definitely fixed. Large-scale industry and wide markets go hand in hand. A wide market of necessity means a multitude of purchasers in practically all walks of life. Large-scale industry in order to live and to expand further must cater to the rank and file, to the so-called common man. In order to obtain enormous supplics, the mass of consumers must give up individuality in demand. Industry is not alone in manifesting this proclivity. Literature, amusement and politics also bend the knee to the great average.

3. Science does not emphasize the importance of the individual. "Science reveals the hard facts of nature in all their brutal realism." It offers nothing which caters to the self-esteem of man. Science makes the individual feel insignificant; he looks like a little wave on the sea of eternity. The masses do not understand scientific thought processes; and, consequently, there is an imminent probability of a new reaction against science. Utopias, socialism, communism and religious leaders offer a world in which the common man shall come into his own and in which the powerful, the wealthy, and the wicked shall be put down.

4. The great increase in population in the last century has also tended to belittle the individual; he is lost in the mass.

If industry is carried on so that the rank and file of workers are made to feel that they are a nondescript group of inferiors, if as consumers they are made to feel keenly the pressure of standardization and uniformity, if science tends to shrink the individual and if the increase in population also tends to bring about the same situation, the rank and file will ultimately discover a way of indicating their industrial significance. In order to avoid unrest and possible upheaval, students of industry should study methods of offering to the workers some opportunity for responsibility in connection with their jobs. One significant task of the individual executive is so to organize industry and to treat employees that opportunity is offered in the work-time for the expression of the instinctive impulse which has been called the "wish for worth," that each worker may feel that he and his work are of importance, significance, and worth in the industrial world. Successful industrial leadership can no longer rest solely upon technical and financial expertness; the industrial leader of tomorrow will be one familiar with the fundamental principles of human engineering and industrial psychology. The new type of industrial leader will be an engineer in industrial relationships.

THE PHYSIOLOGICAL ACTION OF RADIANT ENERGY

By Professor HENRY LAURENS

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GENERATIONS of laymen and physicians have somehow assumed that part of the undoubted beneficial effects of an outdoor life is attributable to sunshine, yet heliotherapy is just emerging from the most empiric of performances into the dignity of a scientifically justified and rationalized procedure. No clear scientific definition of the relationship between sunlight and health was attempted until the later years of the nineteenth century. In 1889 William Huntly stated that sunlight was the thing to counterbalance the evil of the filth and dirt surrounding the natives of Rajputana. In 1889 Finsen published his work on the influence of solar and carbon arc radiation on lupus. In 1890 Palm, an English physician, attempted to show that the geographic incidence of rickets is directly dependent upon the amount of sunlight available. Raczynski in 1912 furnished the first indubitable evidence of the beneficial effect of the sun's rays in experiments on puppies and concluded that the lack of sunlight was one of the causes of rickets. In 1919 Huldschinsky announced the curing of rickets and tetany by means of solar and artificial radiation and his work was soon abundantly confirmed. It has been established that light treatment is excellent for surgical tuberculosis and rickets, and the effects on many other diseases show that we have in this therapeutic measure a stimulant to general health. Skin diseases, chronic anemias, nutritional weakness and wasting in infants, chronic bronchitis, the debility following acute infectious disease, etc., are greatly benefited and the healing of refractory wounds of all sorts is accelerated. While darkness, when the diet is adequate, seems to exert no detrimental influence over long periods of time, the effects of the lack of intense daylight, if not of sunlight, quartz lamp or C arc radiation, when the diet is even slightly unbalanced as to Ca, P and vitamins A and D, on general physical well-being and nutritional conditions is abundantly evident. But while this has been clearly demonstrated, the physiological mechanism by which the results are produced is by no means established.

There is a lack of appreciation as to what radiation embodies, of how the radiation of the quartz lamp and of the C arc differ from that of the sun, of the importance of the intensity of energy, and its duration of action. It should be obvious that if we are trying to copy sunlight we should know something about it as well as about the energy emitted by artificial sources.

Radiation is the process by which energy is propagated through space. Light is radiant energy multiplied by its visibility. The expressions "ultra-violet light" and "infra-red light" are misnomers. Light is that agent, force or action in nature by the operation of which on the organs of sight objects are rendered visible. In other words, it is visible radiant energy. Ultra-violet and infra-red do not render objects visible and they are, therefore, invisible radiant energy.

The intensity of solar radiation is a very variable factor, changing momentarily, daily, seasonally and geographically. On entering the earth's atmosphere about 5 per cent. of the total radiation (1.93 g. cal. per sq. cm. per

min.) is ultra-violet, 52 per cent. visible and 43 per cent. infra-red. Owing to extinction and absorption, by the time the radiation reaches the earth's surface the relative amounts have changed and at average heights of the sun with a total radiation intensity of 1.0 to 1.2 g. cal. per min. per sq. cm. the distribution is approximately ultra-violet, 1 per cent., visible, 40 per cent., and infra-red, 59 per cent. (Dorno). Total intensity is primarily dependent upon height above sea-level, as well as upon seasonal and daily variations, which particularly influence the ultra-violet. Abbot shows that only 75 per cent. of the total solar radiation (the solar constant) reaches a level of 1,800 meters and only 50 per cent. to sea-level. Dorno reports that the variations in the extent of the sun's spectrum into the ultra-violet from summer to winter at midday average 10 mμ, and through the year, from morning until night, about 20 mμ. Summer midday sun is only 10 per cent. richer in infra-red than in winter, in the visible red it is 45 per cent., in the green 90 per cent., in the ultra-violet 1,000 per cent.

The emphasis is always placed on direct sunlight, notwithstanding the fact that skylight has been shown to contain from two to four times as much ultra-violet as does direct sunlight. The influence of skylight has not been studied very much, but Tisdall and Brown find that December skylight in Toronto has a curative and preventive influence on rickets almost as marked as that obtained by exposure to the available sunlight, and Laurens and Sooy obtained similar results on the growth and blood picture of rats in New Haven throughout the year.

The energy emitted by various artificial sources varies not only in spectral distribution but also in intensity as to wave-length, so that comparisons of results obtained from different sources can at best be only very general and superficial unless the total radiant energy as well as that of the various spectral subdivisions is specified in absolute units. If a standard arc, such as an Fe or C arc, be used, such specifications as nature of source, distance from subject and duration of exposure might be regarded as sufficient. But when the Hg arc is used these simple specifications are meaningless. Different Hg lamps vary much in intensity and in the spectral distribution of their energy output. With use they show deterioration, so that even when the energy input is kept constant, which is not often the case, the energy output is increasingly inefficient, particularly with reference to the ultra-violet component.

Of the many sources the sun, the Hg arc in quartz and the C arc burning solid or cored carbons filled with mixtures of rare earths are of practical importance. There is a common belief that the radiation of such sources is solely or mainly active because of the ultra-violet fraction. This may be so, but it has been demonstrated in only a few instances, such as the cure and prevention of rickets, and the formation of melanin in the skin. On the other hand, there is much evidence that the effects are due to the entire spectrum.

I prefer the C arc to the quartz Hg lamp because the rays from the former are more like solar radiations than those obtained from any other source. The Hg lamp is proportionately high in ultra-violet but emits much less heat and visible rays and the short rays, in spite of their intense surface action, have poor penetrating power. It is rays about 300 to 320 mμ long which are most active in producing pigmentation, and they are the ones that are intensified in action by visible or heat rays in the case of the sun and the C arc. These sources produce flushing of the skin during exposure, while the quartz Hg lamp produces no sign of erythema until hours later. The pigmentation produced by

quartz Hg vapor lamps is generally admitted to be inferior to that produced by the sun or the C arc. On the other hand, there is evidence for expecting therapeutic results with other combinations of light rays, certain forms of tuberculosis responding more readily to sources of great intensity in ultra-violet radiation than to solar radiation (Mayer).

There are several methods for determining the amount and character of radiation from different sources. Those based on photochemical reactions are, in general, cumbersome and inaccurate. But one, that of Clark, wherein use is made of the effect of ultra-violet light on lithopone, gives promise of practical value. Pohle uses the photochemical method of Bering and Meyer, in which a solution of hydriodic acid in water frees iodine under the influence of intense radiation. However, at present, the thermoelectric is the logical method of procedure, measuring the intensity of the radiation in absolute units with a non-selective radiometer (thermopile and galvanometer), which can be calibrated by means of a standard of radiation.

Comparison between sources shows the importance of specifying the percentage distribution of the energy emitted. An air-cooled quartz Hg vapor-lamp has a percentage distribution about as follows: 30 per cent. ultra-violet, 53 per cent. visible and 17 per cent. infra-red. In the water-cooled lamps the ultra-violet equals the visible. The energy of a 28 Amp., 60 to 65 volts, flaming C arc is 15 per cent. ultra-violet, 59 per cent. visible and 26 per cent. infra-red. Sunlight at sea-level contains from 1 to 4 per cent. ultra-violet, 42 to 53 per cent. visible, and 57 to 43 per cent. infra-red. Sunlight on Mount Wilson (1750 M) contains from 2 to 5 per cent. ultra-violet, 50 to 55 per cent. visible, and 48 to 40 per cent. infra-red; and on Mount Whitney (4420 M), 2 to 6 per cent. ultra-violet, 54 to 55 per cent. visible, and 43 to 39 per cent. infra-red. We now measure at New Orleans not only the C arc radiation which we use but also sunlight, photographing the spectrum to determine the shortest waves emitted according to season and determining the total energy and its spectral distribution by means of a pyrheliometer.

Owing to the fact that ordinary window glass absorbs wave-lengths shorter than from 320 to 330 mμ there have been developed in recent years, in imitation of quartz, a number of substitutes for window-glass, letting through a considerable proportion of the ultra-violet of sunlight. Some of these are the Corning glass Corex, Vitaglass, Quartzlite glass, paraffin cloth glass, wire-mesh screen glass (celluloidinous material), flexoglass, celoglass, etc.

The appearance of the skin after irradiation with energy containing ultra-violet, visible and infra-red rays is familiar to all. The almost immediate reddening is due to radiant heat (infra-red and luminous rays), frequently has a mottled appearance, is not restricted to the irradiated parts of the skin and disappears soon after the irradiation. It is followed in a few hours by inflammation due to the action of the ultra-violet rays. The usually diffuse and homogeneous redness of this inflammation is confined strictly to the irradiated part and, according to the intensity of the radiation, may be combined with blistering and hemorrhage. The dermatitis is a pathological outcome of the physiological reaction of the skin.

"Light" erythema and pigmentation are the results of action of ultra-violet, but total solar radiation favorably influences the extent and duration of pigmentation, pigment produced by sunlight being of better quality and lasting longer than that produced by either the Hg or the C arc. Pigment is formed by the action of the ultra-violet in sunlight

so that wave-lengths longer than 290 mμ must be effective. Sunlight through glass which cuts off wave-lengths less than between 320 and 330 mμ produces only a slight degree of pigmentation.

Skin pigment probably serves as a screen, reducing the action of ultra-violet and increasing the absorption of visible and infra-red rays by converting them into heat. It does not fluoresce and is not a sensitizer. While it may be, and usually is, an index of the progress of treatment, it does not seem to be necessary to the cure. It is formed particularly following the action of wave lengths from 295 to 305 mμ. One school, represented by Rollier, Lo Grasso, etc., regards pigmentation without erythema as ideal; another avoids pigmentation by irradiating at long intervals but seeks to produce by massive doses as severe an inflammation as possible (the Copenhagen group, Reyn, Sonne, etc.).

There is a general belief that irradiation, particularly with a C arc, produces a greater or less drop in blood pressure, and this has been substantiated in my laboratory, and irradiation with a C arc may represent a form of treatment for some types of hypertension. We have studied the blood pressure, pulse rate and temperature of normal dogs following irradiation with a strong C arc. A maximum decrease of between 15 and 20 per cent. in systolic, and of 10 per cent. in diastolic, pressure occurs after the fifth exposure and reoccurs following subsequent exposures, the normal values being usually regained within twenty-four hours after each exposure. Long lasting depression was obtained in some cases (white, short-haired animals), depressions of 15 to 20 per cent. in both systolic and diastolic remaining for a week and reaching normal on the twentieth day after the irradiations are stopped. The pulse rate usually increases, an average of 20 per cent., during irradiation but returns to normal soon after. Body temperature increases during irradiation by not more than a degree and soon returns to normal.

Many of the observations on the blood picture during and following irradiation have been made under the most diverse conditions: at high altitude, in the tropics, at sea-level, inland and on the shore; with the sun, the quartz Hg lamp and the C arc; on the well, the sick, on children and on adults. There is no wonder that the most diverse results have been described.

We frequently observe and comment on the pale anemic appearance of those working and living in poorly lighted rooms. But it does not necessarily follow that there is in these cases a change in blood constitution, for it is not the Hb content or the absolute number of reds which is decreased by lack of light, but the volume of blood going to the skin. Such anemic looking people often have a surprisingly high Hb content. The case is similar in the members of polar expeditions. Blood studies made during the long winter night show that, in spite of the pale, yellow-green color of the men, there is no change in the blood as long as the food is sufficient. Bernhard, however, is convinced of the harmful effects of the lack of light as exemplified in what he calls the anemic condition of those in the Alps who live on the shady side of the deep valleys as contrasted with those who dwell where they are reached by the sun's rays. Similar effects he claims are reported by many polar investigators, namely, that the Eskimos and members of the expeditions are, at the end of the long polar night, anemic, edematous and weak. Bernhard believes that the reason why changes are sometimes reported not to occur in the blood of members of polar expeditions is that the winters are spent in an illuminated ship and that the failure to find evidences of anemia in mine horses is due to the fact that the mines are artificially illuminated. But recent

observations on mules kept in very dimly lit, almost always dark, mines for from five to ten years show but a slight increase in reds and a corresponding decrease in Hb. The increase in reds is thought to be due to the very good and abundant diet and the hard work that the animals do, an increased metabolism, thus representing an over-compensation against any possible deleterious influence that the lack of sunlight may have.

White, short-haired dogs exposed daily, or at short intervals, to moderate or massive doses of measured C arc radiation show a primary increase of about 30 per cent. in blood volume, evident during the first exposure, accompanied on successive exposures by an increase of about 10 per cent. in red cell number and volume and Hb. The increase in reds is maintained in some experiments, in one animal for six weeks after the last exposure. The red cells in the post-irradiation period are smaller in size and usually of normal saturation. Post-irradiation rises in platelets are frequent, and there is often a post-irradiation decrease in leucocytes.

Although light may benefit general health objectively and subjectively there is no evidence that light baths influence specific immunity. Hartley showed that light baths have not the least effect on specific immunity, although they do increase the general resistance of the body to infection by increasing the bactericidal power of the blood. Van Allen and his coworkers have obtained indication of a relationship between the nature or character of light and the physical state and functional activities of animals and have demonstrated an influence on the course and character of malignant disease in rabbits. C. M. Hill and Clark conclude that the use of ultra-violet radiation is not justified as a general therapeutic agent and that there is little to support the belief that it is capable of increasing natural resistance in normal individuals.

The result of irradiating the organism is to produce, usually, a transitory increase in blood acidity, followed twenty-four hours later by increased alkalinity, which disappears slowly and may last for fourteen days. Fatal doses are always accompanied by acidosis. Man and animals, well and ill, are apparently equally affected and the action seems similar from the short ultra-violet to the hard X-rays. Irradiation produces marked shifts in the serum acid-base ratio as well as shifts in the body minerals. The initial transitory decrease in CO_2 combining power is characterized by an increased flow of acid into the blood; the later and long lasting stage of alkalosis, by an over-compensatory action on the part of the base shifting tissues (Kroetz).

From observations on children and adults at sea-level and at 500 feet in Switzerland, Leonard Hill and Campbell conclude that the rise in metabolism caused by heliotherapy *per se* is insignificant when compared with that caused by exposure to open air. But Kestner and his coworkers found that seashore and mountain sun (and quartz Hg and C arc lamp radiation) strongly and immediately increase gaseous metabolism by action on the skin. The increase is diminished if there is a simultaneous heating effect which brings the chemical heat-regulating mechanism into action. Fries shows that the improved appetite and weight of malnourished children following quartz Hg lamp irradiation is not due to concomitant rise in basal metabolism which, even after repeated exposures during periods of several weeks, does not vary more than 10 per cent. as a rule. She finds no change in the pulse rate and blood pressure as a result of exposure to therapeutic doses of ultra-violet rays. Eichelberger also observed no immediate effect on basal metabolism. following solar and C arc irradiation, but Mason and Mason ob-

tained a decrease following irradiation with a quartz Hg lamp.

It is now established that there are four factors, Ca, P, a vitamin and radiation, the lack of any one of which plays an important part in the production of rickets in infants. Rickets is a disturbance in the metabolism of the growing organism of such nature that the salt equilibrium, in particular as regards Ca and P, in the circulatory fluids is disturbed and lime salts no longer deposit in the bones. Lime salts may not deposit because the ionized Ca in the blood is low, or because the ionized P is low, or because both are low (Park). Exposure to radiation or the administration of cod-liver oil stimulates the deposition of inorganic salts.

Rickets and osteoporosis are of similar origin, being the result of a failure to assimilate Ca and P at normal rates (Hart, Steenbock and Elvehjem). Irradiation can influence the storage of Ca and P and the equilibrium of these elements in the blood stream of mature animals in a way similar to the effects upon growing animals. The antirachitic factor works not only in the retention of Ca in rickets but also in the adult in which rickets is never observed. It represents specifically the organic agent which promotes normal Ca anabolism. It may cure rickets, it may promote growth, or it may simply prevent excessive loss of lime from the body. The specific capacity in which it functions depends upon the condition of the animal, both with respect to age and nutrition, and upon the composition of the ration furnished. When vitamins A and D are completely absent from the diet, radiation can not bring about normality in either growth or bone calcification, the degree to which they approach normality depending upon the pre-experimental store of the factor.

Intestinal absorption plays an outstanding rôle in the effects of radiation. During active rickets considerable amounts of Ca and P are absorbed from the bowel and reexcreted into it. Irradiation prevents much of this abnormal reexcretion as well as promoting absorption from the intestine. The mechanism by which the absorption from the intestine is increased is influenced by two factors, the reaction of the gastro-intestinal contents and the fat intake, as in cod-liver oil. Alkalies diminish mineral absorption, while acids increase it. In infantile tetany, which often complicates the low Ca type of rickets, the acidity of the gastric contents is decreased with consequent decreased Ca absorption, returning to normal with the disappearance of the symptoms. The absorption of Ca is initially dependent on the free acid of the gastric juice, affecting the solution of Ca salts in the diet, and is normally restricted by the alkaline reaction of the intestinal secretions which tend to neutralize and so precipitate lime as insoluble phosphate. It is obvious that the beneficial action of radiant energy and of cod-liver oil is not limited to the rachitic processes. Their action is by supplying something which makes metabolism more efficient, causing the organism to operate with increased economy. They do not bring new processes into operation, but rather permit the organism to have full use of processes which are natural to it but not effective at the time.

Infantile tetany is a condition often complicating rickets and is a symptom complex which occurs in rickets when the salt equilibrium in the blood happens to be of a kind which sets the nervous system in a state of hyperexcitability, namely, low Ca, and it is with the low Ca form of rickets that manifest tetany is associated. Tetany is due to the taking away of Ca from the tissues, while in rickets there is an inability on the part of the bones to bind Ca. Irradiation with a quartz Hg lamp may lead to more marked manifestations of tetany as long as the rachitic metabolic dis-

turbance exists and latent tetany may become manifest. The rachitic tetany sometimes seen at the beginning of treatment is due to the sudden demand for Ca. In florid rickets the blood Ca is practically normal and falls only when healing begins, due to increased need during healing which is met by drawing upon the Ca in the other tissues. It is thus advisable to administer Ca along with the first irradiations. Manifestations of spasm, tetany and convulsions in the early spring may thus be due to sudden and prolonged exposure of children to strong sunlight.

The question as to whether irradiation of the mother produces a protective quality which can be transmitted through the milk has received considerable attention and has been demonstrated to occur in a number of animals and in man. It has been found that sunlight of summer intensity in England has no significant effect in raising the growth promoting value of cow's milk when the diet of the cow is deficient in fat soluble vitamins but does appear to have a small effect in determining the antirachitic value of the milk given. The vitamin A content depends on the diet, but the vitamin D content depends principally upon the degree of insolation of the cow. On the other hand, Hart, Steenbock *et al.* are of the opinion that, either indoors or in direct sunlight, the Ca equilibrium of milking cows is best established by increasing the Ca level and they believe that ultra-violet radiation is not, through direct impingement on the animal, a factor of consequence in the Ca and P metabolism of the dairy cow. Hess reports the production of antirachitic human milk by irradiation of the mother. Rickets was induced in rats after which 25 cc. of human milk was substituted for the rickets-producing diet with no beneficial results, the inorganic P remaining very low. The woman was then irradiated for a month with a quartz Hg lamp. The milk then fed to a lot of rachitic rats had very beneficial results, healing taking place with marked calcification of the epiphyses and increase in inorganic P. This is of some interest when we realize that rickets occurs in from one third to one half of breast-fed infants in the temperate zone.

Of more than usual interest is the demonstration that certain substances inert, in so far as antirachitic, bone calcifying and growth promoting power are concerned, may have these capabilities bestowed upon them by irradiation (Hess, 1924; Steenbock and Black, 1924). The fact that organs such as skin, liver, lung and muscle, as well as body products such as eggs, milk and feces have calcifying and growth promoting properties imparted to them is a matter of scientific and clinical importance. That an animal when irradiated has constituents in its body affected in such a manner that they become antirachitically active has far-reaching implications in connection with our ideas as to the mode of action of radiation, as has the fact that diets which are deficient in certain respects may be made complete by irradiation or by the addition of irradiated substances. A list of the substances which have been activated includes: olive, linseed, cottonseed, corn and nut oil, cholesterol, phytosterol, skin, dextrin, wheat, wheat flour, milk, milk powder, chicken mash, hay, spinach, lettuce, orange juice, yeast and sawdust. Some of the things which have proven refractory to activation are: a solution of chlorophyll, Hb, red blood cells, cream, oleic acid, egg phosphatide, mineral oil, casein and agar.

The presence of cholesterol and its derivatives in the skin and its fatty secretions and the easy absorption by the skin of fats rich in cholesterol, as well as the fact that isolated skin can be antirachitically activated, all imply that a vitamin activated in the skin by radiation is absorbed by the blood stream.

Ergosterol (an optically active sterol possessing three double bonds and a hydroxyl radical), a recently discovered product of great potency, is, in all probability, the naturally occurring parent substance of vitamin D. When irradiated with a quartz Hg lamp it has antirachitic action when as little as 0.003 mg. per capita is fed to rats. Approximately 1 mg. of cholesterol is needed to initiate healing. Ergosterol has the same characteristic absorption spectrum as non-purified cholesterol, the intensity of absorption, however, being enormously increased. Heilbron, Kamm and Morton believe that ordinary purified cholesterol contains another compound in small quantity with well-defined absorption bands (at 293, 280 and 260 mμ), while cholesterol itself has only general absorption. These bands disappear on irradiation with concomitant appearance of antirachitic potency, so that it seems as if the unknown substance is closely connected with the precursor of vitamin D.

In connection with the activation of skin cholesterol, recent work, showing that the efficient agent can be absorbed otherwise than through the intestinal wall, intraperitoneally, cutaneously, subcutaneously and intramuscularly, is of interest. The identity of the influence on Ca metabolism of exposure to ultra-violet and the administration by mouth of cod-liver oil is due to the fact that there are two methods by which the body may acquire the same "antirachitic factor"; that by the action of radiation this substance can be formed either in the cells of the living creature or in its foodstuffs and that many substances can be imbued with the antirachitic factor by exposure to radiation.

It is extremely difficult to formulate any all inclusive scheme of the action of radiation on living organisms. The effects for which we have explanations, based particularly on analogy with nonliving substances, are either physico-chemical or chemical in nature. Between the two there are many phenomena which are only explicable on the basis of a shift from one to the other of these two points of view.

There are indications that radiation can act in more than one way; it may inhibit pathologic processes or destroy pathogenic organisms; or it may conceivably promote some of the bodily functions that are perhaps dependent on a stimulus from without. Finsen at first thought that the radiation with which he cured lupus acted as a bactericide. Later the question arose as to whether the radiation did not act rather as a stimulant to the tissues.

Irradiation acts first directly on the skin, causing an increase in permeability, precipitation of cell proteins and changes in the lipoids; secondly, it may influence the capillary endothelium and nerve endings; and thirdly, it may directly affect the blood proteins.

The therapeutic action of radiation has been regarded by some as due to heat produced locally by absorption, thus speeding up certain processes with no harmful raising of body temperature. Sonne holds that the view that the therapeutic effect of the universal light bath (arc lamp) is essentially due to the ultra-violet rays is not sufficiently warranted and believes that the curative effects are due to the capacity of the luminous rays to heat a very essential portion of the aggregate blood volume of the organism to a temperature possibly exceeding the highest ever measured fever temperature, without causing the body temperature, owing to its heat regulating capacity, to rise to any measurable degree. The specific heat of this blood circulating in the organism acts as a curative agent.

Another view regards the various effects as due to chemical changes in the skin, which bring about influences on distant parts either by reflex action or by diffusion into the blood stream and

transport to the parts affected. Cellular degeneration is a frequent sequel to irradiation of tissues and excessive action of radiation floods the body with too much of the products of tissue damage. Lewis has shown that the action of ultra-violet radiation on cutaneous vessels like other agents such as freezing, burning, etc., which cause tissue injury, sets free in the skin vasodilator substances with histamine-like action which diffuse into the surrounding skin to be then conducted away by lymphatic channels. The vessels become dilated because they lose contractile power and are more or less irresponsive to vasoconstrictor substances and to histamine.

One conception of the effects of radiant energy upon living matter is that the heat effect is due to increased molecular motion while the effect exerted by wave-lengths shorter than about 295 to 300 mμ is due to direct atomic disintegration of the molecules with immediately resulting chemical changes. The effect of radiation of given wave-length is directly proportional to the coefficient of absorption of the protoplasm for that wave-length. All radiation transfers energy to molecules which absorb it and produce heat, but certain frequencies fall into step with the oscillation periods which depend on the molecular structure and so break up the molecule when the energy absorbed is sufficient. The particular kind of radiation which produces this direct action depends on the character of the molecules.

With simpler chemical substances radiation acts as a powerful oxidizing and reducing agent and it may do so with the more complex chemical compounds in the living cell. All photochemical reactions are initiated by a change in configuration and velocity of the electrons of the substance absorbing the radiant energy. If the incident energy has small enough wave-length to produce vibrations in the electrons, instead of in the molecules and atoms, the absorption of energy may result in the activation of electrons. The activated electrons may be ejected, in which case the molecule is ionized, or the electrons may be displaced to an outer orbit, in which case the atom or molecule is activated. In either case they will show altered chemical reactions.

The pathological action of radiation consists in the knocking down of the entire arrangement of the electrons so that their proteins attain an isoelectric state and coagulate. But, even if the effects of irradiation are photoelectric, it is clear that radiation produces some substance or substances in the skin which eventually pass to the blood, so that all the observed effects are the expression of photochemical change.

As a recent editorial in the *Journal* of the American Medical Association pointed out, a demonstrated remedial agent is often liable to be magnified, by the enthusiasts on the one hand, by the unscrupulous on the other, into a universal panacea. Undue exposure to the sun's rays as well as other forms of radiation is by no means an innocuous experience. Inflammatory conditions are familiar as a reaction of excessive sunlight with the production of dermatitis solare. They have usually been attributed to the ultra-violet part of the spectrum.

More or less prolonged exposure to the violet and ultra-violet rays of the sun, and naturally to those artificially produced, may cause not only systemic disturbance but also inflammatory and degenerative changes in the skin, varying with the person. The harmful systemic effects have not been well understood, but deaths following short exposure to ultra-violet radiation have been reported. From a cutaneous standpoint, persons with a mild or moderate susceptibility to ultra-violet and, as has been shown, to the visible violet rays of the spectrum, are not uncom-

mon; severe reactions, however, are rare. Yet it is important to recognize that under certain circumstances a potential susceptibility or an existent cutaneous disturbance due to light sensitization may be made decidedly worse by artificial ultra-violet radiation. Under normal conditions, photosensitive substances are present in living tissue. Under abnormal or pathologic conditions an increase may occur in the amount, or perhaps in the development *in vivo*, of a new photosensitive substance with resultant photodynamic effects from light previously harmless. Since ultra-violet radiation is universally toxic for living cells, these, when hypersensitive to visible light, are apt to develop fulminating effects under such radiation. The basic cause of these effects is said to be a photochemical reaction, the intricate nature of which, however, is not understood as yet.

With the exception of the occurrence in the urine of a decomposition product of Hb there are no diagnostic signs or symptoms of the presence of a potential light sensitization in very young children. When ultra-violet therapy is to be administered to infants, testing doses, to determine tolerance or sensitivity, are therefore advisable. In older children, however, a recurrent eruption on exposed surfaces, particularly if associated with scarring, should be viewed with suspicion.

As Mayer points out, light of any form by itself is not curative but comprises only one of the important adjuvants in treatment. To believe that sunlight or artificial radiant energy will cure; to be unduly optimistic about this treatment and to consider it a specific form of treatment; to use it without sound medical guidance and adequate equipment, and finally to employ it to the exclusion of rest and hygienic-dietetic regimen is bound eventually to dishearten many and to bring discredit to an otherwise desirable method of treatment.

THE INTERIOR OF A STAR AND HOW IT MAINTAINS ITS LIFE[1]

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THE remarkable developments during the past few years in the application of modern discoveries in the structure of matter to the problems of the constitution and operation of the sun and stars form a most fascinating story. I am using the word operation advisedly, since the stars are great engines pouring out radiation at a tremendous rate and constantly renewing their energies from sources deep in their interior. Even at our distance from the sun of 93,000,000 miles, the earth is receiving one horsepower of energy on each square yard of its surface, and were our sun as hot as many of the other stars this amount would be greatly increased. So one of the fundamental problems of physical astronomy is to learn how these huge celestial machines are constituted, what is the nature of the physical forces which govern them, and how matter is modified at the enormous temperatures and pressures to which it is subjected in the stars.

Much of the theoretical and mathematical work on this problem has been carried on by a brilliant group of English physicists, notably Professors Eddington, Jeans, Fowler and Milne, and in this country by Dr. Russell, while the principal American observatories have contributed a large part of the observational material upon which the theoretical groundwork was laid. In trying to place before you some of the results of these extensive investigations I shall make no attempt to treat them individually, but rather to outline in a simple way the general conclusions to which they lead us as regards the dynamics of stars, their evolution, and the time-scale within which their changes occur.

At the outset it is desirable to emphasize the remarkable uniformity of nature so far as concerns the materials with which we have to deal. In the most distant stars and the remote universes of the spiral nebulae we find the same elements with which we are familiar upon our earth and which we recognize so easily in our sun. Even in their relative proportions they do not seem to differ greatly, and if we could imagine our earth heated through the successive stages ranging up to that of the hottest stars we could match it at almost every stage with some star within our field of knowledge. So the atoms with which we have to do are the same atoms which we know in our physical laboratories, but under the influence of such extraordinary conditions, especially in the interior of stars, that they are modified almost beyond recognition.

It is a rather interesting coincidence that physically a man is nearly a mean proportional between an atom and a star. It requires about 10^{27} atoms to make a human body and the material of 10^{28} human bodies to make an average star. An atom is less than one one-hundred millionth of an inch in diameter and bears nearly the same relationship in size to a golf ball that a golf ball bears to the earth. Small as this volume is, we find within it the complicated structure of the atom with a central nucleus surrounded by rings or rather shells of electrons revolving about it in definite orbits very similar to those of the planets about the sun. We can then picture an undisturbed atom as a minia-

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ture solar system in which the distances of the electrons from the nucleus are quite comparable with the distances of our planets from the sun, but in which the velocities of revolution are enormously high, an electron making a million billion complete revolutions each second. All electrons are alike, being simply the natural units of electricity, but their number differs for each element and defines most of its properties. Thus hydrogen has but one electron, while iron has 26 and uranium no less than 92.

In spite of its extraordinarily small mass, which is roughly the fraction of a grain represented by 1 preceded by 25 ciphers, the energy possessed by an electron in any one of its orbits is a small but definite quantity. In the earlier theories of the radiation of energy it was supposed that light and other radiation was given out by an electron as it moved in its orbit, but it is now realized that radiation can be produced only when there is a change of energy, that is, when the electron jumps from one orbit to another and gains an excess of energy by the transfer. This excess it at once emits as definite radiation which may be visible to the eye, if it occurs within the range to which the eye is sensitive, or, if not, may be detected as heat or X-ray radiation. In other words, it produces a spectral line, the spectrum being simply an analysis of all the radiation which is given out by the excited atoms in a radiating body.

We see then that in order to excite an atom and so to produce radiation we must apply an outside source of energy to an atom sufficient to make its electrons jump from one orbit to another. This is done most simply through the application of intense heat, and the most convenient way of securing such heat in the physical laboratory is by the use of an electric current. So the element to be studied is vaporized by an electric arc, spark, or electric furnace, or, in the case of a gas like hydrogen, a current is passed through a tube filled with the gas at a very low pressure. In each case the application of this external energy disturbs the equilibrium of the electrons in the billions of atoms of the vaporized element, and they begin to jump from one orbit to another giving out radiation whenever the orbit into which they pass has less energy than that from which they started. All the electrons which make the same transition give the same radiation or the same spectral line, and since in the elements with many electrons a great number of different transitions are possible we obtain a spectrum rich in spectral lines. Even in the case of the simplest atom, hydrogen, there is good evidence that about 20 of these excited states can exist.

We can perhaps best illustrate these relations from the consideration of a very simple atom like that of hydrogen. Here we have only one electron revolving around a central nucleus. If an electric current is passed through a tube of hydrogen at low pressure, the electron is pulled out of one orbit into another and then flies back again. Since the inner orbit has less energy than the outer the electron has an excess of energy which it gives out in the form of radiation and produces a spectral line. It is as though the electrons were held by elastic strings which are momentarily stretched and then snap back into place. Hydrogen with its single electron has a comparatively simple spectrum, but iron with 26 electrons has some 2,000 lines in the visible spectrum.

If sufficient energy is applied from the outside, as in the form of a very powerful electric current or electric spark, it is possible not only to pull an electron out of its orbit, but even to detach it completely from the atom. In such a case the atom is said to be ionized and the character of its radiation, or its spectrum, is modified profoundly. It

has been found possible in the physical laboratory to detach as many as six electrons from the atoms of one or two of the elements and thus to produce multiple ionization. Another method of detaching electrons from atoms is by bombarding a gas with atoms from a radioactive substance like radium. This gives off atoms of helium which move with a velocity of about 10,000 miles a second. A collision of one of these atoms with an atom or molecule of a gas results frequently in knocking off one or more electrons which are momentarily free, although they very soon combine with other atomic systems. Still another method of producing free electrons is by the collision of X-rays with atoms. X-rays are ether waves of extraordinarily high frequency of vibration, and when one of them strikes an atom a very frequent result is that an electron absorbs the energy of the wave and flies away from the atom in a wild career which ends quickly with its capture by another atom. I have referred to these processes by which free electrons are produced because they play an exceedingly important part in the mechanism of the sun and stars.

We can now pass to a consideration of how atoms behave in the huge aggregations of matter which form the stars. But before doing so I should like to review briefly a few of the facts which we know about the stars that constitute our stellar system. In the first place they are very numerous. Under good conditions the naked eye can see about 6,000 stars over the whole celestial sphere, while a small telescope will show several hundred thousand. A large telescope adds immensely to the number, and it is estimated that about one billion stars can be photographed with the 100-inch reflecting telescope at Mount Wilson. Every one of these stars is a self-luminous body like our sun, with a surface temperature ranging from about 2,000° centigrade (3,600° F.) in the case of the coolest stars, to about 25,000° centigrade (45,000° F.) for the hottest stars. Our sun has the very moderate temperature on this scale of about 6,000° centigrade.

The stars are extremely far away from us. The nearest star so far known, apart from our sun, is at a distance of 25 million million miles, and the most distant stars we observe are probably 20,000 times as far away as this. Because of this immense variation in distance, the brightness of a star as it appears to us is no criterion of how bright it actually is. It may appear bright because it is relatively near us, or because it is very bright intrinsically. Of the two brightest stars in the sky, Sirius, the Dog Star, is comparatively near, while Canopus, the famous star of Egypt, is very distant but enormously bright intrinsically, giving out about 10,000 times as much light as our sun. The great range in the intrinsic brightness, or what we might call the candle power, of the stars is one of the most interesting facts of astronomy. The ratio amounts to 750,000,000 for stars already known, which is about the difference between a candle flame and a powerful electric searchlight.

Another important fact about the stars is the great range of their size and densities. Our sun, which is a comparatively small star, has a diameter somewhat less than 900,000 miles and a mean density 1.4 times that of water. Among the stars, however, we find that Antares, the brightest star in the constellation of the Scorpion has a diameter 300 times as great as the sun, or about 250,000,000 miles, while its mean density is less than one one-millionth of water or below the lowest vacuum which we can attain with our air pumps in the physical laboratory. At the other end of the scale we find stars with diameters no larger than those of the planets in our solar system, only a few thousand miles across, but with densities ranging up to many thou-

sand times that of water and far beyond the density of any element which we know upon the earth. Our heaviest elements like platinum are only about 22 times as heavy as water.

It is a most significant fact that the giant stars like Antares of enormous size have a very low density, while the dwarf stars of small size like the faint companion of Sirius have a very great density, since this means that the masses of stars do not differ by any such amount as we should expect from their size or brightness. The same result is shown by observations of double stars, which afford a direct means of determining masses. The evidence all tends to indicate that the masses of stars do not show any great range, only a few hundredfold at most, while their luminosities, volumes, and densities differ by factors of hundreds of millions. The probable explanation of this fact, as of many of the others to which I have referred, lies in the extraordinary physical conditions present in the stars and in the profound modifications which atoms experience deep in the interior of these stellar furnaces.

A star such as our sun, which may be taken as a typical dwarf star of its class, is a huge mass of gas at a very high temperature. There can be little doubt that it is gaseous all the way through, for no elements could exist in a solid, or probably in a liquid form, even at the temperature of its surface which is about 6,000° centigrade. Above the visible surface of the sun extends an atmosphere of gases reaching up for thousands of miles, visible at the time of a total eclipse as a ring of light surrounding the disk of the moon. Beyond this in turn is the corona, extending out to a distance of hundreds of thousands of miles. The surface of the sun is, of course, exposed to the intense cold of space, and the only way in which the enormous loss of energy through radiation can be made good is through a constant renewal of the supply from the interior of the sun. So we are at once faced with the question: What can we learn regarding conditions inside the sun and the behavior of matter when subjected to the enormous temperatures and pressures which there prevail?

Our direct observational knowledge of a star is, of course, limited to but a very small fraction of its volume. To penetrate into its interior we must use what Eddington has called an "analytical boring machine," that is, extend our data by the application of general physical and mathematical principles. These show at once that the temperature in the interior of a star is to be reckoned in millions of degrees and the pressure in millions of atomspheres. What does an atom do under such conditions?

In the first place it is evident that all the electrons except the innermost ones will be stripped from the atom and that the interior of the star will be filled with free electrons which fly about in all directions and are detached and recombine with extraordinary rapidity. A second result of these terrific temperatures is that radiation in the interior of the star will be enormously intense and mainly in the form of very short waves such as X-rays. These ether waves seek to pour out toward the surface of the star like a great wind, but on their way they encounter the mutilated atoms and electrons of the closely packed gases which tend to obstruct their progress. The result is an outward pressure toward the surface of the star, the pressure of radiation.

All radiation exerts pressure. The lights in a room exert pressure against its walls, although at such temperatures as we can obtain in our laboratories the amount is very small. Its measurement by Russian and American physicists about thirty years ago was a remarkably skilful piece of accurate research. But when we pass to masses and tempera-

tures, such as the stars possess, the pressure of radiation becomes extremely powerful and may even counteract the force of gravity which holds the stars together. To illustrate, if we consider a series of spheres of gas with masses of 10 grams, 100 grams, 1,000 grams, and so forth, each differing in mass from the preceding by a factor of 10, we find that the pressure of radiation is quite negligible as compared with the forces which hold the mass together until we get into very large figures. When the mass reaches 10 with 32 ciphers, however, the pressure of radiation becomes a considerable fraction of the force of gravity, and beyond 10^{34} it exceeds it. At this point, then, we might expect something to happen, and in Russell's happy phrase "what happens is the stars." The mass of the sun is $2x10^{33}$ grams, or about $2x10^{27}$ tons. If a star were much less in mass than this, radiation would not be great enough to maintain its equilibrium, and, if it were much greater, it seems probable that radiation pressure would blow it apart. So we find that nature after all keeps an accurate account of the number of ciphers and does not tolerate much deviation from a definite model. In Eddington's opinion a mass range of five to one would include 90 per cent. of the stars.

Returning then to the interior of the star, we find a mixture of atoms, electrons and ether waves in the wildest state of agitation. An interesting picture is drawn by Eddington in one of his recent lectures at Oxford from which I should like to quote a single paragraph.

"Dishevelled atoms tear along at 100 miles a second, their normal array of electrons being torn from them in the scrimmage. The lost electrons are speeding 100 times faster to find new resting places. Let us follow the progress of one of them. There is almost a collision as an electron approaches an atomic nucleus, but putting on speed it sweeps round in a sharp curve. Sometimes there is a side-slip at the curve, but the electron goes on with increased or reduced energy. After a thousand narrow shaves, all happening within a thousand-millionth of a second, the hectic career is ended by a worse side-slip than usual. The electron is fairly caught and attached to an atom. But scarcely has it taken up its place when an X-ray bursts into the atom. Sucking up the energy of the ray the electron darts off again on its next adventure."

The result of this wild confusion in the interior of a star is that while the atoms and electrons are battered back and forth with little permanent change of position, the ether waves do make gradual progress toward the star's surface, and finally emerge, perhaps after thousands or millions of years, transformed at the lower temperatures of the outside of the star into the light and heat waves which the astronomer observes and by which he is enabled to test the products of the physicist's calculations.

A very interesting consequence of the conditions in a star's interior is the possibility of the existence of very high densities. As we have already seen, an atom is like a miniature solar system with the distances between the electrons and the nucleus comparable with those between the planets and the sun. In the case of our terrestrial atoms, then, the limiting density is reached when the outer electrons are nearly in contact, which occurs usually when our substance is in the liquid state. Thus a liquid is nearly incompressible. In the stars, however, where the outer electrons have been stripped off, the atoms can be packed very much more closely together and the density can rise to extraordinarily high values. If we could imagine a star in which the atoms had been robbed of all their electrons, so that nothing but the central nuclei remained, we should find densities millions of times greater than we know upon the earth. Probably

this does not occur in the stars since the innermost electrons of an atom can in all probability be detached only with the greatest difficulty. The loss of even the outer shells of electrons, however, is amply sufficient to make possible densities which at first thought seem almost fantastic to those who deal with matter under terrestrial conditions. Our evidence for the existence of such densities in the stars, nevertheless, is strong, and this in spite of the fact that the stars are wholly gaseous.

An interesting and in some respects unique means of testing the conclusions of physical theories of the densities possible in the interior of stars is afforded by the faint companion of Sirius, the brightest star in our sky. This star forms a physical system with Sirius, and hence we are able to determine its mass, which is nearly equal to that of the sun, and about two-fifths of that of Sirius itself, although its brightness (and in this case its real luminosity since the distances of the two stars are equal) is only 1/10000 part as great. For many years it was supposed that the companion was at a very low temperature, which would account for the small luminosity of a star of such large mass, but observations made at Mount Wilson about 13 years ago showed that its spectrum is very similar to that of Sirius itself. This left us with the choice of two alternatives: either that a star can have a spectrum which so far as we know is always associated with a high surface temperature and yet actually be at a very low temperature, an assumption which is repugnant to our scientific methods of thought; or, that the star is of very small size and hence, in consequence of its large mass, of extraordinarily high density.

A direct test of these alternatives is afforded by the theory of generalized relativity. This requires that there should be a displacement of the spectral lines which depends directly on the mass of a star and inversely on its radius. In the case of our sun, and most of the stars, this displacement is very small because the radius is large, although very accurate observations of the solar spectrum by St. John have proved its existence definitely. If, however, the size of the companion of Sirius is as small as theory would indicate, the relativistic displacement should be comparatively large and capable of observation. The problem was undertaken at Mount Wilson and the results found indicated the presence of the displacement in almost exactly the amount predicted by theory. The observations are difficult because the star is faint and involved in the glare of its brilliant neighbor, but there is as yet no reason to believe that the measurements are incorrect. They would lead to a radius for the star about 1/30 that of our sun and a density 36,000 times as great. This would be about 50,000 times the density of water, or 2,000 times that of platinum.

Densities even greater than this are indicated for one or two other faint stars in the sky, although direct observational tests such as we have for the companion of Sirius are lacking in their case. A faint star discovered by van Maanen is found to show a spectrum which points to a relatively high surface temperature, and a mass which, as derived from the relationship connecting mass and luminosity, is about one seventh that of the sun. The resulting diameter is about that of the earth and the corresponding density 400,000 times that of water. A cubic inch of such material would weigh no less than seven tons! Although stars of this type seem to be comparatively rare, there are great numbers which have an average density at least equal to that of solid iron.

The stars of which we have been speaking are all dwarf stars. If we pass to the huge giants, millions, and in some cases hundreds of millions of miles, in diameter, we find just the opposite state

of conditions. The mean density of the bright star Capella is just about that of our air, so that a human being could just breathe comfortably were he placed in the interior of Capella and were he not discommoded by a temperature of a few millions of degrees and an atmosphere consisting mainly of flying electrons. Inside of Antares he would find a density lower than that of the most perfect terrestrial vacuum and would speedily come to grief.

I cannot close this brief consideration of the densities of stars without a reference, once more taken from Eddington, to the remarkable consequences which would follow if we had among the stars a globe of the size of Betelgeuse and a mean density equal to that of the sun. We have already seen that its diameter is about 200,000,000 miles and its density about one-millionth that of water. If it had a density 1.4 times that of water, which is the average density of the sun, three results would follow according to the modern theory of gravitation:

"First, owing to the great intensity of its gravitation, light would be unable to escape; and any rays shot out would fall back again to the star by their own weight.

"Second, the relativistic displacement would be so great that the spectrum would be shifted out of existence.

"Third, mass produces a curvature of space, and in this case the curvature would be so great that space would close up round the star leaving us outside—that is to say, nowhere."

Eddington concludes by remarking "except for the last consideration, it seems rather a pity that the density of Betelgeuse is so low."

Perhaps the most fundamental of all the questions connected with the physical processes in the stars, and at the same time the most difficult to answer, is what keeps up the enormous supply of energy. For many years it was believed that the contraction of the stars, with the resulting conversion of mechanical energy into heat and light, was the true explanation, but recent additions to our knowledge show that this is quite inadequate. An outstanding difficulty is that it does not give us time enough. In the case of our sun it gives us about 20,000,000 years back to the time of its origin, but this is by no means enough for all the processes of cosmological and geological time. Something like 1,000,000,000 years is much more nearly the minimum period required. For giant stars, which pour out their energy hundreds or thousands of times as fast as our sun, the period of life history is cut down to quite inadmissible limits.

So we are forced to seek another explanation, and one which will provide the source of energy in the interior of the stars themselves. Here we find a supply of enormous magnitude, and one equal to every demand upon it, in the energy of constitution of atoms and electrons, that is, in the positive and negative electric charges out of which matter is made. If this energy can be released, either in part by a redistribution of the electrons and nuclei into forms involving less energy, or in whole by a complete annihilation of the atoms themselves, the result will be a supply of inconceivably great amount.

The first of these two processes would result in the transmutation of the elements, such as is familiar to us in the gradual changes of radioactive substances. If several atoms of the simplest of all elements, hydrogen, were to be combined to form one atom of a more complex element, about 0.008 of the mass of each atom would be lost in the change and would be released in the form of energy. For example, if a pound of hydrogen were transformed into helium, an atom of which is made up of four hydrogen atoms, the result would be 0.992 pound of helium and 0.008 pound of energy. This last figure sounds very

small, but 0.008 pound of energy is rather more than 430 billion horsepower. So if we can think of the sun as originally a mass of hydrogen gas which has gradually been transformed into the various elements that we now find within it, the energy released in the process would keep the sun shining for about 10 billion years. The time-scale afforded in this way seems to be ample, even for the vast periods required by cosmological history.

If instead of concluding that a part of the atomic energy is released by the transmutation of elements, we assume that all of it may be made available by the complete annihilation of matter, our supply of energy would become very much greater. In this case our pound of hydrogen would give us a pound of energy instead of 0.008 pound, and our total supply would be multiplied by a factor of 125. Our sun, on this hypothesis, would be radiating away its mass at the rate of 120 thousand billion tons a year and the material now contained in it would be sufficient to maintain the present rate for about 15 thousand billion years longer. At the end of that time no mass would be left.

As between these two views of the source of energy of the stars, the transformation of matter and the annihilation of matter, there is perhaps not very much to choose. The latter would give us the larger supply and the longer time-scale. It would require that in the past the stars should have been much more massive than they are now, and this in turn would have favored their close approach and the conditions under which we believe our planetary system had its origin. In behalf of the hypothesis of the transmutation of the elements we may say that the very fact of the existence of helium and other more complex elements in the stars is good evidence for their possible formation from hydrogen in the great chemical laboratories which the interiors of stars provide. There is no philosophical view more deeply imbedded in the scientific mind or more complete in the satisfactions it affords than that of the development of matter, or of life, from the simpler to the more complex forms.

A very natural question to ask at this point is: Can the results of observation afford any evidence as to the destruction of matter in the production of radiation? In one very important respect it can. If a star loses mass by radiation the older stars in the evolutionary sequence should be less massive. This is just what observation shows. In the main chain of dwarf stars, which includes the great majority of stars in our system, a regular progression with age is found, the older stars being less massive, more dense, less luminous, and of a lower surface temperature. The fundamental discovery by Eddington that the luminosity of a star depends directly upon its mass shows at once that it can progress along the evolutionary sequence only if it loses mass. Otherwise, it will stand still at a point defined by the original quantity of matter in it. Even if we assume that energy is supplied by the transformation of elements, it is evident that a stage will be reached when the process will be complete, and the star will become extinct. On the other hand, if matter can be radiated away as energy, radiation will cease only with the annihilation of the star itself.

The picture then of the probable course of evolution of our sun which this theory gives us is about as follows: We may assume that at present it is in equilibrium, with the amount of energy radiated balanced by the supply of subatomic energy from the interior. As it loses mass it attempts to readjust its internal conditions to correspond. A drop in temperature takes place in the interior which reduces the supply of energy below the amount lost by radiation. The sun then contracts, the temperature rises, the energy increases, and the sun

regains its equilibrium. The process repeats itself again and again, each time resulting in a loss of mass and an increase in density. Our last clear view of it would be as a faint red star, of small mass and high density, one of the vast number of such stars which people our stellar universe.

One final consideration of profound interest is that of the possible reversibility of the process of radiation. If matter can be annihilated to produce energy, can energy recombine, as it were, to form matter? Of the energy poured out by the sun less than one two-hundred-millionth part is intercepted by the planets, and a quite negligible amount by the stars, while the flood of radiation from the stars themselves passes out into remote space quite unchecked except for the small quantities absorbed by the nebulae. Is it possible that radiation is finally reflected back from the boundaries of a limited space, or do we have in the nebulae some mechanism by which the energy released from matter can be stored up once more in the form of atoms and electrons? Such considerations are purely speculative, for we know of no process of this kind. If it does exist, we can picture our physical universe as renewing itself and perpetually changing; if it does not exist and energy is finally dissipated, the end will be that pictured in the first chapter of Genesis with "darkness upon the face of the earth."

In this brief outline of some of the more important applications of modern physical theory to the stars, I have not touched upon many of the difficulties which exist, some of which may modify considerably our present views. We can not weigh and measure the material in the interior of stars and can only extend to it the physical laws gained from the limited conditions of our laboratories. Broadly speaking, however, the picture of the stars which we obtain is a consistent and a most illuminating one. The progress of science is in large measure due to the bold and skilful investigators who do not hesitate to push their conclusions to the utmost limits, since only in this way can we learn the strength and the weaknesses of the foundations of our knowledge and test the firmness of the structure erected upon it.

FOUR OLD ASTRONOMICAL OBSERVATORY BUILDINGS

By Professor FLORIAN CAJORI

UNIVERSITY OF CALIFORNIA

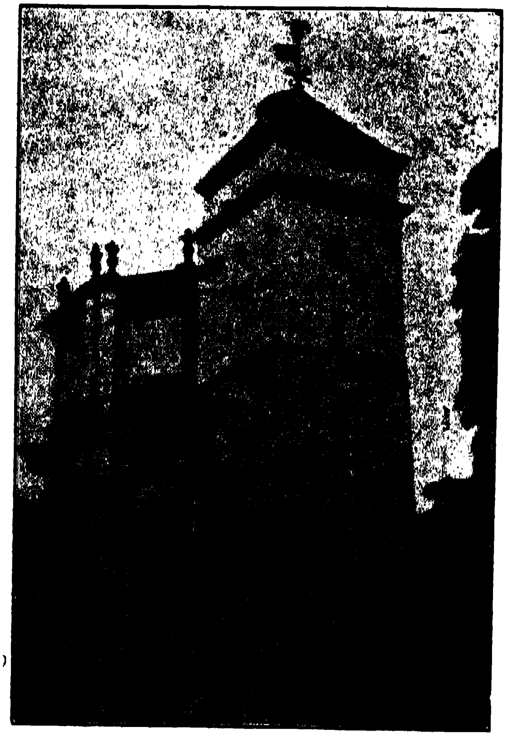
THERE are three seventeenth century European observatories of permanent type which are of interest because of the record of discovery associated with them. We refer to the Observatories of Copenhagen, Paris and Greenwich. The observatory at Copenhagen was built by King Christian IV of Denmark, apparently as a reparation for the indifference to astronomy shown in the time of his minority by permitting the renowned astronomer Tycho Brahe to be deprived of his observatory at Uranibourg and to abandon his native country. The observatory at Copenhagen was completed in 1642, the year, as it happened, in which Galileo died and Newton was born. The inscription on the building is partly in words, partly in symbols and partly in abbreviation. The whole inscription, as interpreted in words by a Copenhagen official, Bering Liisberg, is: *Doctrinam et justitiam dirige, Adonai, in corde coronati Regis Christiani Quarti* (Guide the faith and justice, Oh Jehovah, in the heart of King Christian IV). The observatory constituted the tower of "Trinity," a student church at the university of Copenhagen. In 1728 this tower and church were damaged by the great fire of Copenhagen. The astronomical instruments in the tower were destroyed, including the famous celestial sphere of Tycho Brahe which had been sent back from Prague as booty in the Thirty Years' War. Astronomical observations were made in an apartment at the top of the tower. In the second half of the seventeenth century great changes took place in the design of astronomical instruments, in consequence of which the Copenhagen observatory as well as the one in Paris were found to be inadequate in design. When Roemer in 1681 returned from Paris to Copenhagen, he found that instruments at the top of the tower were disturbed by strong winds. He turned his private residence into a temporary observatory. However, astronomical work was carried on in the old round tower until the year 1861, when a new observatory was finished. The astronomer T. N. Thiele, whose son is now a mathematical astronomer at the University of California, was one of the last observers in the old round tower of Copenhagen.

The tower has been regarded a masterpiece of art and is still one of the attractions of the city. Visitors ascend 35 meters to the top by a spiral avenue. The tower consists of two hollow concentric brick cylinders, the interior one being about three meters in diameter, the outer one about 16 meters in diameter. Between these is the spiral avenue, made famous by the spectacular rides in 1716 made by Peter the Great of Russia and his Queen. The astronomer Horrebow states in one of his books that Peter the Great frequently ascended the tower on horseback along the spiral avenue, and that the Empress Catherine occasionally ascended at his side in a four-wheeled chariot drawn by six horses!

The Paris Observatory was begun in 1667 and completed in 1671. It was one of the enterprises carried out by Louis XIV and Colbert, his minister of finance,

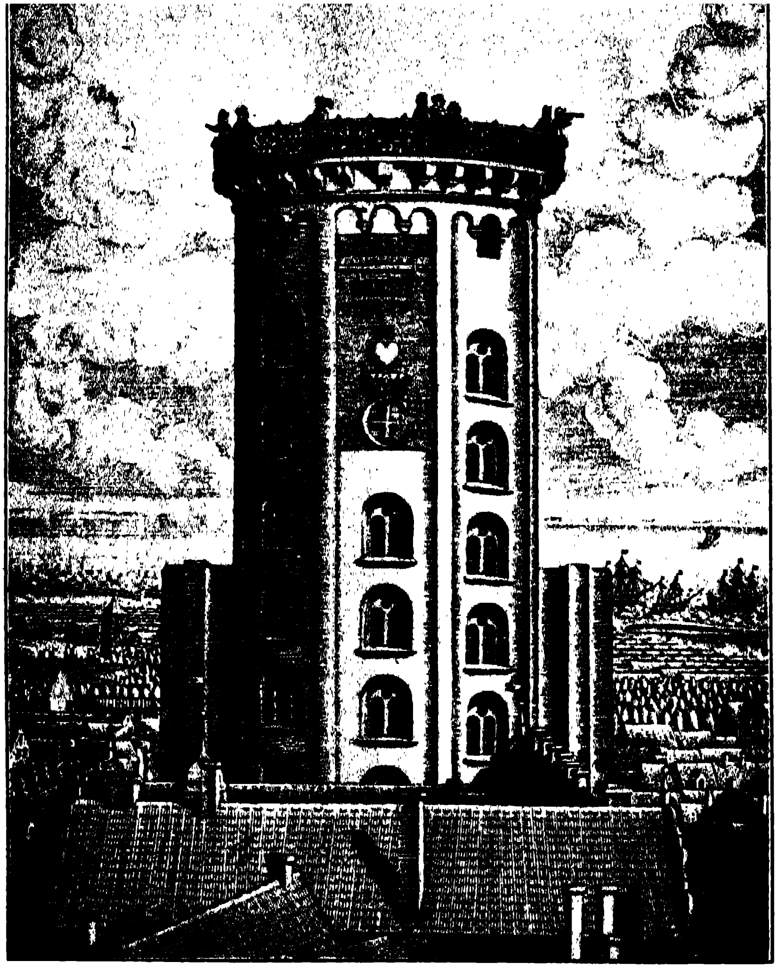
for the glory of the reign. A great building and great astronomers added luster to French science. Christian Huygens was called to Paris in 1666, Jean Dominique Cassini came from Italy in 1669, Olaf Roemer from Denmark in 1671. Jean Picard was making his celebrated measurements of the earth which Newton used in testing the law of gravitation. The Paris Observatory was a stately edifice, planned by the architect Claude Perrault, noted for his colonnade of the Louvre. The observatory consisted of a quadrangular pile, flanked by two massive towers. In after years the flat roof was altered in appearance by the addition of several domes. Otherwise the building retains at the present time its seventeenth century appearance. Frequent criticism has been passed upon it because, as Robert Grant states in his "History of Physical Astronomy," "no means were provided in the construction of the building for enabling the astronomers to observe celestial bodies at all altitudes, by means of instruments sheltered under its roof, nor was it possible to repair this omission on account of the enormous thickness of the walls." The illustration of the building and grounds which we give is more instructive than other pictures of it that we have seen, for the reason that it exhibits more of the astronomical instruments then in use. We see here the old Huygenian type of telescope with a long tube. Achromatic lenses were then unknown. To enhance the magnifying power without excessive chromatic blurring of images, the focal length of the objective lens was increased. This necessitated telescopes with very long tubes. The figure shows also the old-fashioned clumsy quadrant. On a table is an armillary sphere. The picture bears testimony also to the interest in astronomy taken in early days by women.

The observatory at Greenwich has a somewhat different history than the ones



THE OBSERVATORY AT BOGOTA, 1803, THE EARLIEST PERMANENT OBSERVATORY BUILDING IN AMERICA

at Paris and Copenhagen. There was no marked attempt at architectural display; the structure was planned by the practical astronomer, Flamsteed, and the mathematician and architect, Christopher Wren. The motive which led to the initial steps for erecting the observatory was not to add fame to the reign of the King of England, nor to give luster to British science, but to serve the practical needs of British seamen. It was a time when navigation ceased to be confined to the Mediterranean and to the coasts of continents, when ships ventured into the unmeasured expanses of the great oceans. It became necessary to know the positions of ships, in particular, to determine the longitude of a place at sea. The method of "dead reckoning" was extremely inaccurate and inadequate. An amusing incident



THE COPENHAGEN OBSERVATORY, BUILT IN 1642 BY KING CHRISTIAN IV, AND STILL VISITED BY TOURISTS
(*Courtesy of H. Thiele.*)

is told of Commodore Anson who wanted to reach the island of Juan Fernandez near Chile to obtain fresh water and provisions. Believing that he was west of the island, he sailed eastward; really he was east of it and was sailing away from it as fast as the wind would carry him. The commercial position of Great Britain and its standing as a world empire depended upon its navigation. The Greenwich Observatory was erected to observe the motions of the sun, moon and planets and to secure accurate star catalogues that were needed for the more reliable computation of longitude. And yet, this observatory, built to answer practical needs, has contributed powerfully toward the advancement of science.

Greenwich Observatory was founded in 1675 in the reign of Charles II. "A gate-house demolished in the Tower supplied wood. . . . The sum of £500, actually £520, was further allotted from

THE PARIS OBSERVATORY, ERECTED IN 1667 BY LOUIS XIV
THIS PICTURE SHOWS MORE FULLY THAN OTHERS THE TYPE OF INSTRUMENTS USED BY ASTRONOMERS OF THE SEVENTEENTH CENTURY

the results of a sale of spoilt gunpowder; and with these limited resources Greenwich Observatory was built." Our picture shows the observatory in the days of Flamsteed, the first Astronomer Royal. "Whenever any part of it was found insufficient for its purpose," says Newcomb, "new rooms were built for the special object in view, and thus it has been growing from the beginning by a process as natural and simple as that of the growth of a tree."

Ask an astronomer which is the oldest permanent observatory building in America and he will probably make an incorrect reply. The oldest permanent observatory on our continent is at Bogota in Colombia, a city at one time considered "the Athens of South America." The observatory was erected in 1803 through the prestige and persuasion of the Spanish scholar José Celestino Mutis, a friend of Alexander von Humboldt. Mutis and Francisco José de Caldas, a native scientific enthusiast whom he had trained, took observations with instruments mainly of European construction. After the death of Mutis and after Caldas became a martyr in the cause of his country's independence from Spain, regular astronomical work ceased at Bogota for the larger part of the nineteenth century. It is for that reason that the observatory is not generally known to astronomers. But about the beginning of the present century scientific work was resumed and since 1922 special emphasis is placed at the observatory upon meteorological and magnetic observations.

The observatory at Bogota was an expensive structure for that day, costing 13,815 pesos. It was built for the advancement of science and also as an ornament to the capitol of what was

GREENWICH OBSERVATORY IN THE TIME OF FLAMSTEED, THE FIRST ASTRONOMER ROYAL

then New Granada. The design was made by the Capuchin Fray Diego Domingo Petréz. Caldas called the building "the first temple erected to Urania in the New Continent." It was an octagonal tower over 18 meters high. Our illustration exhibits the tuscan pilasters fitted to the angles of the octagonal structure. Prominent in our photograph is a tower on a side of the main octagonal part, which provided a spiral stairway to the upper floors.

THE PROGRESS OF SCIENCE

THE RETIREMENT OF DR. FEWKES

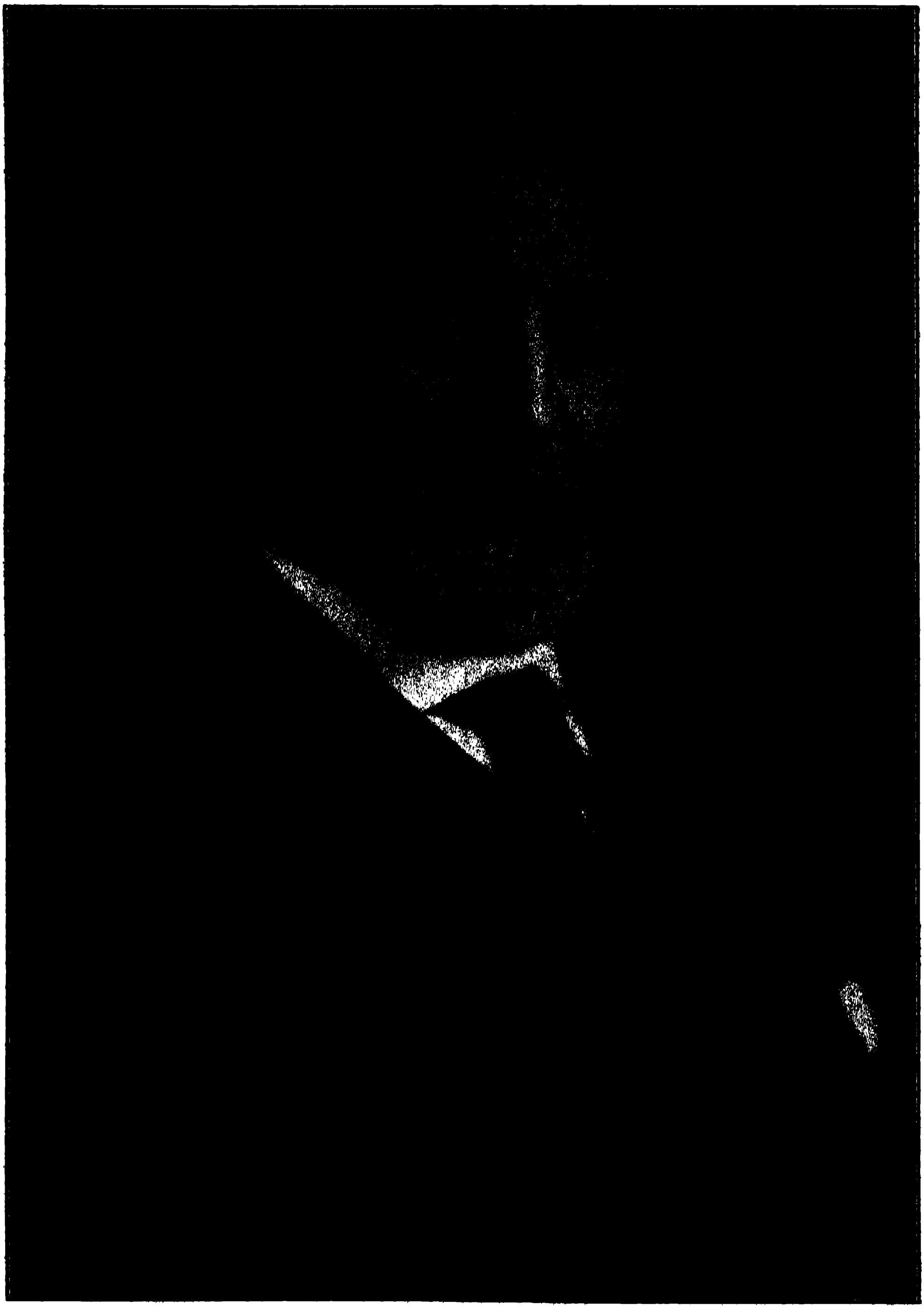
DR. J. WALTER FEWKES, chief of the Bureau of American Ethnology under the Smithsonian Institution for the past ten years, has retired as administrative head of the bureau and will devote himself entirely to research.

Dr. Fewkes is one of the few white men who have been initiated as a priest into the secret rites of the Hopi Indians. He was the first man to make use of the phonograph in recording Indian music. He introduced the principle of preservation into archeological research in this country, so that excavation of the ancient Indian monuments of the land was transformed from a looting operation to one of preservation. His work made Mesa Verde National Park a center of pilgrimage for thousands annually and a national show place. He gathered one of the largest and finest collections of Indian pottery ever brought out of the southwest. He founded and edited the *Journal of American Ethnology and Archeology*. On the immense quantity of data collected by him will rest much of the future work in American archeology and ethnology.

The retiring chief of the Bureau of American Ethnology is one of the few living disciples of the great naturalist, Louis Agassiz. As an undergraduate of Harvard University, Dr. Fewkes turned his attention at first to physics and published some results of original researches in electricity. In 1873, however, he attended the Agassiz School at Penikese Island, Buzzard's Bay, and for the next fifteen years he devoted himself to zoology, specializing in the lower invertebrates. He worked and studied both in this country and at Leipzig, Naples and in France. During most of this time he was connected with the Museum of Comparative Zoology at Harvard University.

A trip to California in 1887 gave the final bent to his interests by absorbing him in ethnological problems, especially of the Pueblos. In the summers of 1889 and 1890, Dr. Fewkes visited Zuni, New Mexico, and in the latter year first employed the phonograph in recording primitive music. He became deeply interested in primitive religion, and spent four years in the study of the ritual of the Hopi, in the employ of the late Mrs. Mary Hemenway. He was initiated into the Antelope and Flute priesthoods of the Hopi, and consequently witnessed and was able to describe for the first time many secret ceremonies of the tribe. In 1894 he published what now stands as the classic account of the famous Walpi Snake Dance. The Hopi gave him the name of "Naquapi," which means Medicine Bowl. They named him, so they said, because he was like a medicine bowl in that they were always pouring information into him.

Dr. Fewkes' connection with the Smithsonian Institution began in 1895 when he engaged in field work for the institution. He collected at Sikyatki pueblo, Arizona, one of the finest collections of pottery ever brought out of the southwest, distinguished by delicacy and variety of coloring and decoration, and perfection of form. Twenty years later he made another collection of prehistoric pottery from the Mimbres Valley, New Mexico, from which he was able to show the existence of an extinct people, possessed of the most realistic art of any people of the southwest. The decorations included live figures, humans, animals, birds and hunting scenes, as well as striking geometric designs.



DR. J. WALTER FEWKES

RETIRING CHIEF OF THE BUREAU OF AMERICAN ETHNOLOGY

The publication of Dr. Fewkes' first work under the Smithsonian marked the beginning of intensive archeological work on southwestern cliff-houses and pueblos. His outstanding archeological achievement among many is the excavation and repair, begun in 1908, of many of the cliff dwellings and temples situated in Mesa Verde National Park, Colorado. His work on Spruce Tree House and Cliff Palace, two of the largest cliff dwellings in the southwest, was one of the pioneer projects for the thorough excavation and repair of ruins in the prehistoric pueblo area. Aside from their value in connection with the prehistory of the American Indians, the restorations have made of the park a life-size museum from which thousands take away annually a more just conception of the culture of the people the white man displaced.

The number and extent of the researches and excavations which Dr. Fewkes has initiated as a pioneer give him perhaps a unique place in American archeology. They include work among the native peoples of Porto Rico and the West Indies, an archeological survey of the Gulf Coast of Mexico, excavations in Trinidad and the Lesser Antilles, and more recently investigations of Florida and South Carolina mounds.

Though retired from active service, Dr. Fewkes will retain a study in the Smithsonian with the Bureau of American Ethnology and continue his own researches, adding to his already imposing list of scientific publications. His successor as chief of the bureau has not yet been appointed.

AIRPLANE SAFETY

THE new automatic slotted wings for airplanes, invented in England and now being given their first American trials on Navy planes, will reduce the aviation death lists considerably if their performance in practice lives up to their showing in tests. More than eighty per cent. of the fatal accidents in aviation are due to stalling, spinning and nose-diving. The automatic slots attached to an ordinary airplane cure the stall and tend to make the airplane safe.

"Stalling" is the nightmare of every pilot. Good ones or bad may stall their craft when they try to land too slowly, climb too quickly, or land a plane with a dead engine. When the flying speed of the plane reduces to a certain point, the "lift," or supporting force on the wings caused by the rush of the plane through the air, decreases. The plane then tends to slip backward, as it were, and the pilot can not make it obey the ailerons or other controls. It spins and plunges downward toward earth. If the pilot knows enough and is high enough when a stall occurs, he can eventually right and save his ship. But if the altitude is low or the pilot unskilled, a crash is practically sure to follow.

The Handley Page automatic slotted wings come into action when the plane is about to stall and become uncontrollable. They consist of slats or flaps on the front edge of the wings that, when the plane is flying normally, form a part of the wing structure. When the wing loses lift, however, the slat opens under the lifting force of the air on the slat itself. A slot is created in the wing and this so changes the characteristics of the airplane wing that it keeps the plane under control and prevents it from getting into a spin. Even an incompetent pilot can not stall his plane, according to claims made for the new device.

Slotted wings have been known for about ten years. Manually operated types were developed in England by the Royal Air Force and in Germany, but these had the disadvantage of needing action on the part of the pilot to put

them in operation. The Handley Page automatic slots were developed secretly in England and have only had limited demonstration there. The plane that has just been demonstrated here is so far the only one in America to be so equipped. It is an American-made NY training plane, as designated by the government, and equipped with pontoons to take off and alight on the water.

THE NINE-HUNDRED-THOUSAND-VOLT CATHODE RAY TUBE

In receiving the Edison Medal from the American Institute of Electrical Engineers for his work on lamps and X-ray tubes, presented to him in February, Dr. W. D. Coolidge, of the General Electric Company, announced the latest product of his researches, the triple-cascade cathode ray tube operating on 900,000 volts and capable of sending out into the air a stream of electrons with a velocity of 175,000 miles per second.

The new tube is a sort of three-in-one arrangement of the first tube Dr. Coolidge announced two years ago at the Franklin Institute, which operated at 300,000 volts. He tried building larger individual tubes, but found limitations to the voltage that could be used. He then tried out the cascade arrangement, whereby the rays from one tube would be fed into another, which would speed them up and feed them along to still another and in this way developed the 900,000 volts tube.

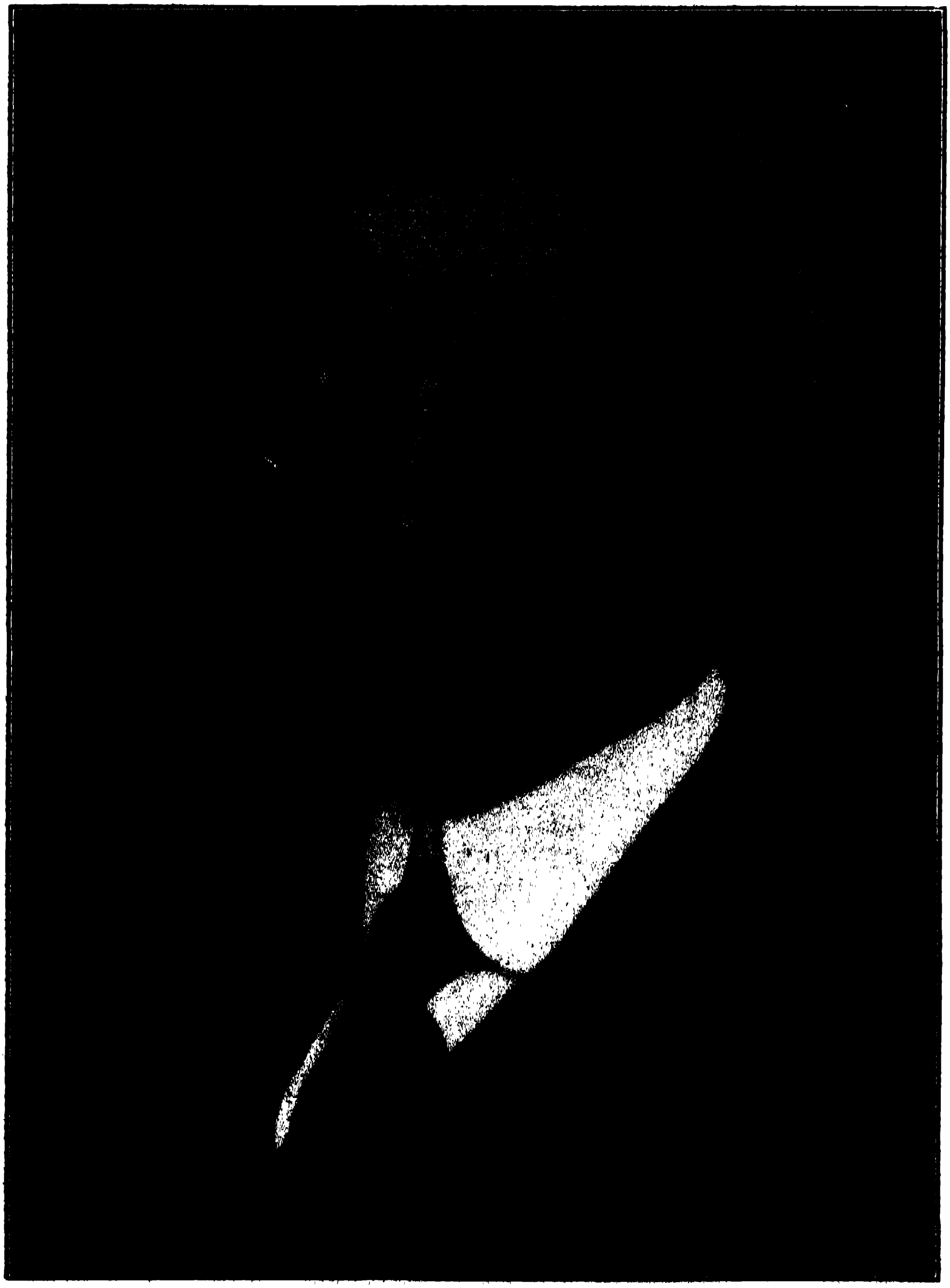
The electrons expelled from the tube, appearing in a ball of purplish haze, are shot forth at the rate of 175,000 miles per second, which is the fastest speed ever accelerated by man. This is about 350,000 times faster than the speed of a bullet shot from an army rifle.

"Just what the use will be for these high-speed particles obtained from the tube is still a problem," Dr. Coolidge says. "We shall experiment with them. They should eventually help us to further knowledge of radiation laws and of the atomic nucleus. It is not unlikely that therapeutic, chemical, bactericidal and other practical uses will develop."

The tube is about 95 inches long and has three bulbs, each 12 inches in diameter. The window from which the electrons are emitted is of thin metal foil, but one ten thousandth of an inch, or one quarter that of an ordinary piece of writing paper, in thickness. This is absolutely hole-proof and is so constructed as to withstand total atmospheric pressure of more than 100 pounds, the difference between the outside air and the almost perfect vacuum within the tube. A heated tungsten filament, originally used by Dr. Coolidge in his X-ray tubes, furnishes the supply of electrons. The glass tube is shielded with a copper tube so that the stream of electrons can not strike the glass and cause punctures.

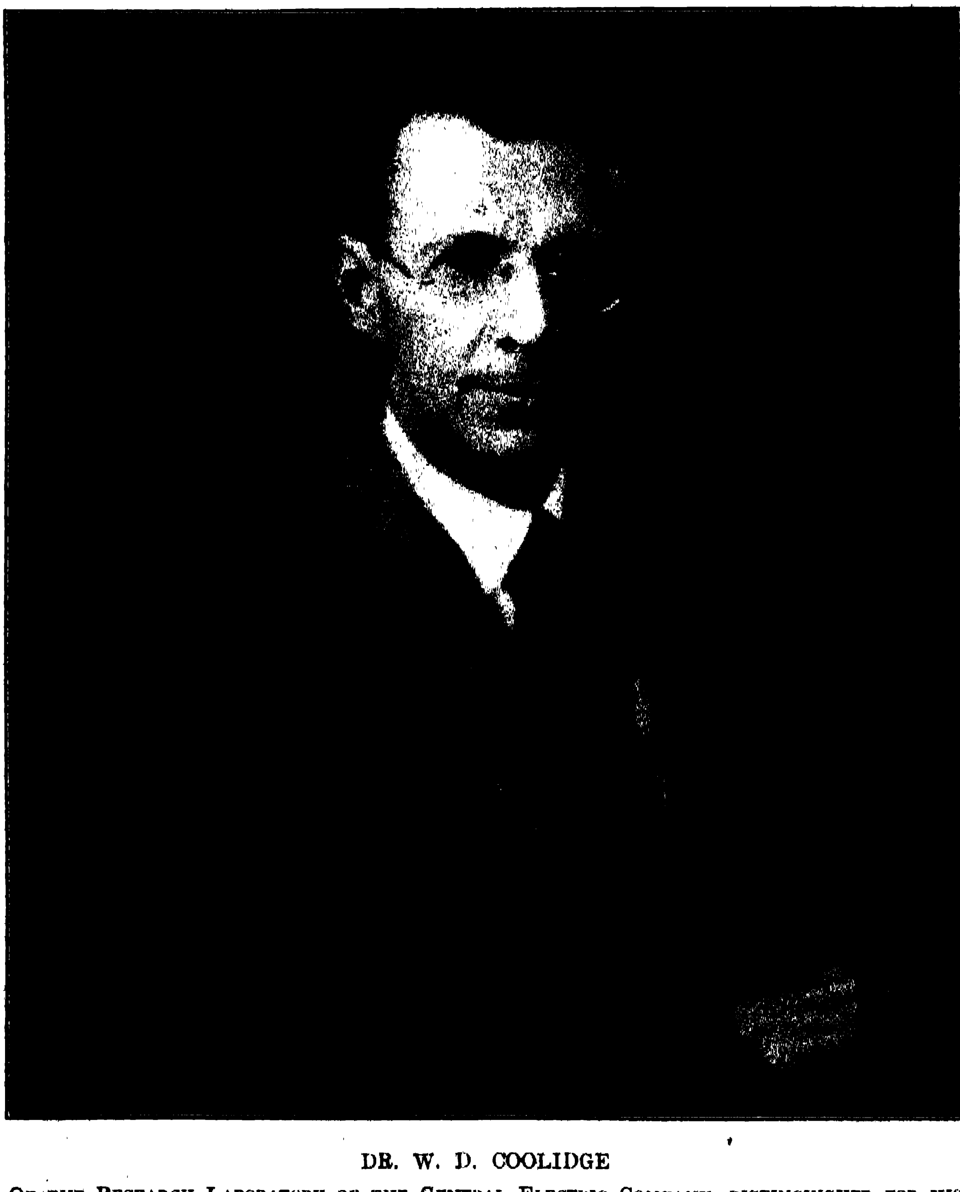
"In our earlier attempts to build experimental X-ray and cathode ray tubes for voltages appreciably in excess of 250,000, we have seemed to be continually contending with and limited by the 'cold cathode' effect," Dr. Coolidge said. "More recently we have found that we can remove this limitation, by subdividing the total potential difference applied to the tube between different pairs of tubular electrodes. The electrons are then given successive accelerations as they pass between successive pairs of electrodes. This, in effect, divides the tube up into sections each of which may be good for as much as 300,000 volts. We have already successfully operated such a cathode ray tube with three sections on 900,000 volts.

"This cascade or multisectional system promises to let us build vacuum discharge tubes for as high voltages as we can produce. This applies as well to an X-ray tube as to a cathode ray tube, as the latter may be converted into the former by the addition of a suitable target. It also



HERMANN M. BIGGS

WHO AS PROFESSOR OF MEDICINE IN THE UNIVERSITY AND BELLEVUE HOSPITAL MEDICAL COLLEGE, CHIEF MEDICAL OFFICER OF THE NEW YORK CITY HEALTH DEPARTMENT AND NEW YORK STATE COMMISSIONER OF HEALTH, PERFORMED A SERVICE FOR PUBLIC HEALTH THAT WILL LAST LONG AFTER HIS DEATH.

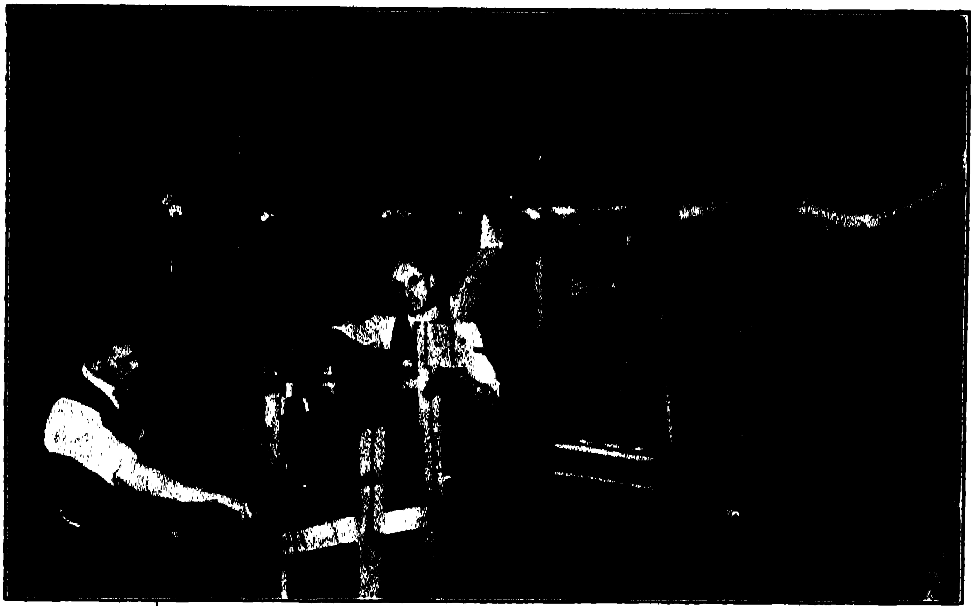


DR. W. D. COOLIDGE

OF THE RESEARCH LABORATORY OF THE GENERAL ELECTRIC COMPANY, DISTINGUISHED FOR HIS WORK ON X-RAY TUBES AND CATHODE RAYS

applies equally well to a high voltage kenotron.

"This opens a vista of alluring scientific possibilities. It has tantalized us for years to think that we couldn't produce in the laboratory just as high-speed electrons as the highest velocity beta rays of radium and just as penetrating radiations as the shortest wave-length gamma rays from radium. According to Sir



THE NEW TRIPLE-CASCADE CATHODE RAY TUBE

Ernest Rutherford, we need only a little more than twice the voltage which we have already employed, to produce X-rays as penetrating as the most penetrating gamma rays from radium and three million volts to produce as high speed beta-rays. The intensity factor would be tremendously in our favor, as with twelve milliamperes of current we would have as many high-speed electrons coming from the tube as from a ton of radium in equilibrium with its decomposition products. Another factor in our favor would be the control which we should have of the output. This would be quite different from our position with respect to radium, in which case no physical or chemical agency at our command in any way affects either the quality or the quantity of the output.

"We expect to find that a high-voltage positive ray tube can be constructed along the general lines of the multi-sectional cathode ray tube. In this case, we should need, according to Rutherford, about eight million volts to produce positive rays having the energy of the highest velocity alpha rays from radium.

"The problem of vacuum-tube operation at very high voltages is a twofold one, as it involves not only the design of the tube but also the design of a suitable high voltage source.

"It seems quite possible that it will prove advantageous to proceed along the lines of our present oil-immersed X-ray outfit, in which the X-ray tube is placed in the same container and in the same oil with the high-voltage source. With such an outfit no part of the high-tension circuit is brought out into the air, and the corona problem is therefore greatly simplified.

"We now have transformers good for several million volts, even with the high-tension circuit brought out into the air, and it should be possible for us to go much higher than this if the whole high-tension circuit is kept in the oil."

A NEW ENGINEERING LABORATORY FOR LEHIGH UNIVERSITY

LEHIGH UNIVERSITY plans for the erection of a new Electrical and Mechanical Engineering Laboratory which will be one of the finest in the country. The new building will be the largest on the campus and will cost approximately a million dollars.

The laboratory will be collegiate Gothic in style with walls of native stone trimmed with cut limestone. It will have an over-all width of 225 feet and a depth of 184 feet. The largest division of the building is devoted to the main laboratory which will be occupied by both the mechanical and electrical engineering departments and will be spacious enough to accommodate the heaviest machinery, boilers, generators, etc. Ample provision is made throughout the building for offices and class-rooms, as well as numerous small research laboratories and others for the standardization of delicate measuring devices. An auditorium, a museum and library are additional features.

The new building will be provided with modern and fully-equipped machine shops. Four large drafting rooms are provided for the several branches of engineering drawing. A number of small laboratories will be devoted to the study of problems peculiar to electrical communication.

The laboratory is designed with lighting, heating and ventilation equipment of the most modern, efficient and effective type. The electrical engineering equipment will include a complete electrical sub-station, a high-voltage and traction laboratory and storage battery rooms. Special attention will be given to the installation of the multiplicity of electrical wiring in large conduits where they will be concealed.

President Richards' outline of the pressing need for this new building stresses the importance of laboratory work as an adjunct to the study of natural laws. Pointing out that Lehigh's enrolment in electrical engineering has increased 51 per cent. in the last three years, it is shown that the present laboratory facilities are rapidly becoming inadequate.

THE SCIENTIFIC MONTHLY

MAY, 1928

THE INFLUENCE OF BODILY LOCOMOTION IN SEPARATING MAN FROM THE MONKEYS AND APES

By Professor HENRY FAIRFIELD OSBORN

HONORARY CURATOR OF VERTEBRATE PALEONTOLOGY, AMERICAN MUSEUM OF NATURAL HISTORY

By far the most interesting problem in anthropology to-day is that of our Tertiary ancestors. Were they ape-men or Dawn Men? If we were to actually discover the complete skeleton of a pro-man in Lower Miocene or Oligocene time, would it be more like a man or more like an ape? The latter opinion is the widely prevailing one at the present time, and against it I raised, at the bicentenary meeting of the American Philosophical Society last April, what I call the Dawn Man theory, and I went so far as to stigmatize the ape-man theory as a myth.

Myth, derived from the Greek word muthos, signifying "legend," is defined[1] as "a legend; a traditional story, often founded on some fact of nature, or on an event in the early history of a people, and embodying some religious belief of that people." What I term the "ape-myth" rests upon no such slender evidence as a single fact in nature; it has grown up through more than a century of substantial observations in zoology and comparative anatomy; it is buttressed by recent discoveries in the development of the human brain, in the embryonic and foetal development of man, by many facts in the fossil history of man, and it is now supported by all the ablest and keenest students of human ancestry on the anatomical side—Sir Arthur Keith, Professor G. Elliot Smith, Professor William King Gregory, Professor J. Howard McGregor, Professor Frederick Tilney, Dr. Dudley J. Morton—also by many anatomists of a much more radical school, such as Dr. Hermann Klaatsch, who derives different races of man directly from different races of anthropoid apes.

Against such an array of profound and widespread research, as well as of character and sincerity, I feel like a youthful David stepping out to oppose a mighty Goliath. I admit that evidence on either side of this most interesting and friendly controversy is still not absolutely conclusive and that in the end Goliath may throw a stone more forceful than David's! In some fundamentalist quarters it is alleged that I have recanted the theory of the ascent of man from a much more primitive stage. This, of course, is the very reverse of my present Dawn Man theory of human ancestry, which may be expressed as follows:

Man sprang from partly tree-living (arboreal), partly ground-living (terrestrial) higher primates, of the kind known as "anthropoid" because of their nearer resemblance to man than to the

[1] The Winston Simplified Dictionary, 1926.

FIG. 1. THE LONG, SLENDER FINGERS OF THE GIBBON ADAPTED TO HYPER-ARBOREAL, BRACHIATING LIFE. SCENE FROM "CHANG," A PARAMOUNT PHOTOPLAY.

monkeys, baboons and lemurs. The fingers of the ancestral hand were broad and separated, the thumb well developed, with grasping power; the toes of the ancestral foot, on the contrary, were brought together, and the big toe was slightly separated. Thus in both the hand and foot these pro-human anthropoids were adapted both to tree and to ground progression. Neither hand nor foot was so far specialized for extreme arboreal life as to be disabled for an early tool-making power of the hand and for a nearly bipedal and cursorial power of the limbs and feet. Similarly, the pro-human brain conserved the alertness of all smaller primates in the terrestrio-arboreal stage but retained the potentiality of directing separate motions of the fingers and thumb in shaping defensive and offensive weapons, and the potentiality of directing rapid motions of the limbs and feet in bipedal, cursorial life, defensive and offensive.

This theoretic picture of *adaptation to habit* in our Dawn Man and pro-Dawn Man ancestors is, in my opinion, largely sustained by the embryonic, the foetal and the adult structure of the human hand and foot. These prenatal locomotor organs afford evidence of arboreal adaptation *far antecedent to the highly specialized brachiating or limb-swinging hand and limb-grasping foot of the anthropoid apes.* In other words, according to the Dawn Man theory the human family branch scientifically known as the *Hominidae* has since Lower Miocene and perhaps Upper Oligocene time been independent from the ape branch known as the *Simiidae* or snub-nosed primates. The innumerable resemblances between apes and man in functional, anatomical, psychical and physiognomic characters

are, by the Dawn Man theory, interpreted partly as parallelisms or convergences and partly as heritages from a common stock technically known as the primate Order *Anthropoidea*.

Origin of the Ape-man Myth

Children, behold the Chimpanzee:
He sits on the ancestral tree
From which we sprang in ages gone.
I'm glad we sprang: had we held on,
We might, for aught that I can say,
Be horrid Chimpanzees to-day.
—Oliver Herford.[2]

The ape-man myth has a long prehistory. The natives of the East Indies who observed the gibbon and the orang and the natives of Africa who observed the chimpanzee and the gorilla independently assigned human names to these anthropoid apes. Early naturalists, such as De Bry (1598), Hoppius, a pupil of Linnaeus, Tyson (1699), represented the apes as walking erect, and they supplemented the accounts of explorers by exaggerating human resemblances. The strong resemblances of the apes to man was cited by Buffon in a veiled suggestion of relationship. Lamarck went further and said that in the evolution of man from the ape the erect position was necessary to free the hand. Du Chaillu was forced by his publishers to exaggerate human characteristics of the gorilla, and the French sculptor Fremiet put into bronze the mythical stories of the gorilla in erect attitude closely resembling man. Recently Carl E. Akeley demonstrated the true locomotor habits —on all fours—of this giant ape, confirming the accurate observations of several naturalists. Haeckel, like other early disciples of Darwin, grossly exaggerated the ape-human resemblances in his "Anthropogenie" by placing ape skeletons all alike in a false erect position, while Huxley in his masterly "Man's Place in Nature" contended, against his great opponent Owen, for the close kinship of the apes to man.

[2] "The Poetry Cure," by Robert Haven Schauffler, p. 54.

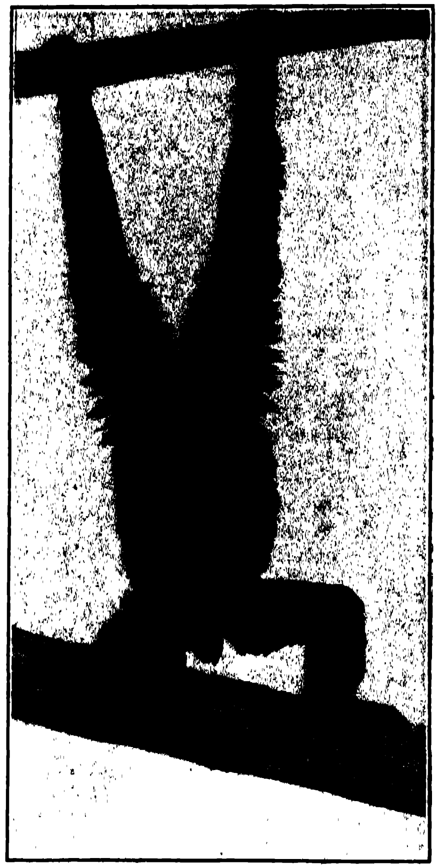


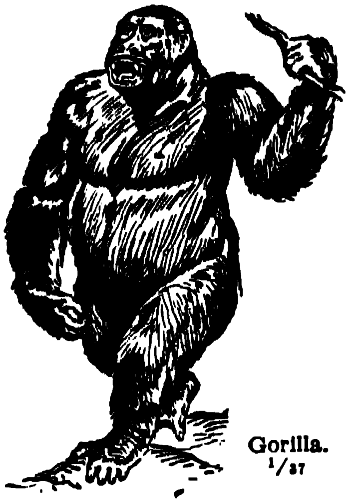
Fig. 2. The hooked hands (angulodactyly), elongated arms, short legs, spreading big toe of the black Gibbon. Courtesy New York Zoological Park.

Origin of the Ape-man Theory

Beginning with Darwin in 1874, there has been a continuous and more or less theoretic discussion, first as to the kinship of man to various lower primates, second as to the point in the lower primate scale from which the human family was given off. Darwin's opinions are clearly set forth in the following citations:

As we have no record of the lines of descent, the pedigree can be discovered only by observ-

the Gorgon's spell; petrify.
or"gon-zo'la, 1 gōr"gen-zō'la; 2 ḡôr"ḡōn-zō'la, *n.* A cheese of pressed milk made at Gorgonzola, Italy.
;o-ril'la, 1 go-ril'a; 2 ḡo-rĭl'a, *n.* A manlike and ferocious African ape about five and a half feet in height, with a massive body and limbs. [< Gr. *gorilla.*]
;or'ki, 1 gōr'kı; 2 ḡôr'ki, **Maxim.** See PYESHKOV.
gor'mand, } 1 gōr'[*or* gour'mand, } gūr']mend; 2 ḡôr'[*or* ḡụr']mand, *n.* **1.** A glutton. **2.** An epicure; gourmet. [< F. *gourmand,* glutton.] — **gor'mand-ize,** *vt.* & *vi.* [-IZED; -IZ"ING.] To eat voraciously. **gor'-mand-ise‡.** — **gor'mand-iz"er** or **-is"er.** *n.*



Gorilla.
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FIG. 3. THE GORILLA AS DEFINED AND PICTURED IN FUNK AND WAGNALLS'S DESK STANDARD DICTIONARY (1917).

ing the degrees of resemblance between the beings which are to be classed. (1874, p. 199.)

If man had not been his own classifier, he would never have thought of founding a separate order for his own reception. (1874, p. 201.)

There can, consequently, hardly be a doubt that man is an offshoot from the Old World Simian stem; and that under a genealogical point of view, he must be classed with the Catarrhine division. (1874, p. 206.)

If the anthropomorphous apes be admitted to form a natural subgroup, then as man agrees with them not only in all those characters which he possesses in common with the whole Catarrhine group, but in other peculiar characters . . . we may infer that some ancient member of the anthropomorphous subgroup gave birth to man. (1874, p. 206.)

But a naturalist would undoubtedly have ranked as an ape or a monkey an ancient form which possessed many characters common to the Catarrhine and Platyrrhine monkeys, other characters in an intermediate condition, and some few, perhaps, distinct from those now found in either group. And as man from a genealogical point of view belongs to the Catarrhine or Old World stock, we must conclude, however much the conclusion may revolt our pride, that our early progenitors would have been thus properly designated [namely, as monkeys]. (1874, p. 207.)

It is therefore probable that Africa was formerly inhabited by extinct apes closely allied to the gorilla and chimpanzee; and as these two species are now man's nearest allies, it is somewhat more probable that our early progenitors lived on the African continent than elsewhere. (1874, p. 208.)

The Simiidae then branched off into two great stems, the New World and Old World monkeys; and from the latter, at a remote period, Man, the wonder and glory of the Universe, proceeded. (1874, p. 221.)

The foot was then prehensile, judging from the condition of the great toe in the foetus; and our progenitors, no doubt, were arboreal in their habits. (1874, p. 215.)

Nearly all the other and more important differences between man and the Quadrumana are manifestly adaptive in their nature, and relate chiefly to the erect position of man; such as the structure of his hand, foot and pelvis, the curvature of his spine and the position of his head. The family of seals offers a good illustration of the small importance of adaptive characters for classification. These animals differ from all the other Carnivora in the form of their bodies and in the structure of their limbs, far more than does man from the higher apes; yet in most systems, from that of Cuvier to the most recent one by Mr. Flower, seals are ranked as a mere family in the Order of Carnivora. (1874, p. 200.)

From what we see going on under domestication, we learn that some of the co-descendants of the same species may be not at all, some a little, and some greatly changed, all within the same period. Thus it may have been with man, who has undergone a great amount of modifica-

tion in certain characters in comparison with the higher apes. (1874, p. 209.)

The recent views of William King Gregory, as fully detailed in his successive masterly papers since 1916 ("Notharctus Memoir," "Our Face from Fish to Man," etc.), have been summarized by him (1928) as follows:

An impartial reading of the 1916 paper will show a surprising agreement in general viewpoint with Darwin's, although it was written entirely independently and I regret to say with all too scant knowledge of Darwin's writings.

Since 1916, in many papers, I have defended the view that man is an offshoot of some early member of the anthropoid stock, more or less nearly related to some of the wide-ranging dryopithecoid group and that his nearest existing relatives are the chimpanzee and the gorilla. I prefer not to quibble about whether the long-snouted, long-tailed, tree-living primate with grasping hands and feet, assumed as man's very remote ancestor, should be called by some less pleasant name than monkey.

In many papers since 1916 I have cited evidence tending to show that however long the final plains-living, cursorial stage may have lasted, it was immediately preceded by an arboreal primitive anthropoid stage with a gorilloid type of foot.

The stage preceding the terrestrial, cursorial biped has, to my mind, always been a brachiating pro-anthropoid, nearer on the whole to the chimpanzee than to Homo sapiens but without the extreme arboreal specializations of the orang.

The last paragraph is italicized because it contains the gist of Gregory's present theory. Sir Arthur Keith, following his studies on all the previous literature, including Gregory's researches,

FIG. 4. THE ARBOREAL, LIMB-SWINGING, BRACHIATING ORANG, WITH HOOKED FINGERS, ABBREVIATED THUMB, SPREADING BIG TOE. COURTESY NEW YORK ZOOLOGICAL PARK.

FIG. 5. THE SECONDARY ARBOREO-TERRESTRIAL CHIMPANZEE, WITH POWERFUL HOOKED FINGERS (ANGULODACTYLY), GREATLY ABBREVIATED THUMB, ENLARGED BIG TOE. FULLY ADULT STAGE. COURTESY NEW YORK ZOOLOGICAL PARK.

in his notable address[8] before the British Association, concludes:

No one can compare the teeth of the(se) Miocene anthropoids with those of primitive man, as has been done so thoroughly by Dr. William King Gregory, and escape the conviction that in the dentitions of the extinct anthropoids of the Miocene jungles we have the ancestral forms of human teeth.

It is useless to go to strata still older than the Miocene in search of man's emergence; in such strata we have found only fossil traces of emerging anthropoids. All the evidence now at our disposal supports the conclusion that man has arisen, as Lamarck and Darwin suspected, from an anthropoid ape not higher in the zoological scale than a chimpanzee, and that the date at which human and anthropoid lines of descent began to diverge lies near the

[8] Sir Arthur Keith: "Darwin's Theory of Man's Descent as it Stands To-day." Presidential address to the British Association, Leeds, England, August 31, 1927.

beginning of the Miocene period. On our modest scale of reckoning, that gives man the respectable antiquity of about one million years.

Thus the highest British authority (Keith) and the highest American authority (Gregory) of the present time agree not only as to man's strong kinship to the apes but as to man's descent from a primitive ape-like form more closely resembling the chimpanzee than man but less specialized in ape-like habits than the orang.

When we concentrate our attention on the form and functions of the hand and foot, on the relative proportions of the limbs, on the age-long effects of the bipedal cursorial habit of our own ancestors in contrast with the quadrumanal arboreal brachiating habit of the ancestors of the anthropoid apes, I reach widely different conclusions from my colleagues as to the relationship of man to the apes.

Proof of Man's Kinship to the Apes

All pioneers in this most interesting discussion have naturally tended to dwell upon the resemblances in the brain and other organs rather than to summarize the profound differences in the entire locomotor organization.

Gregory (November 18, 1927) has compiled tables (not yet published) which he entitles "Significant Marks

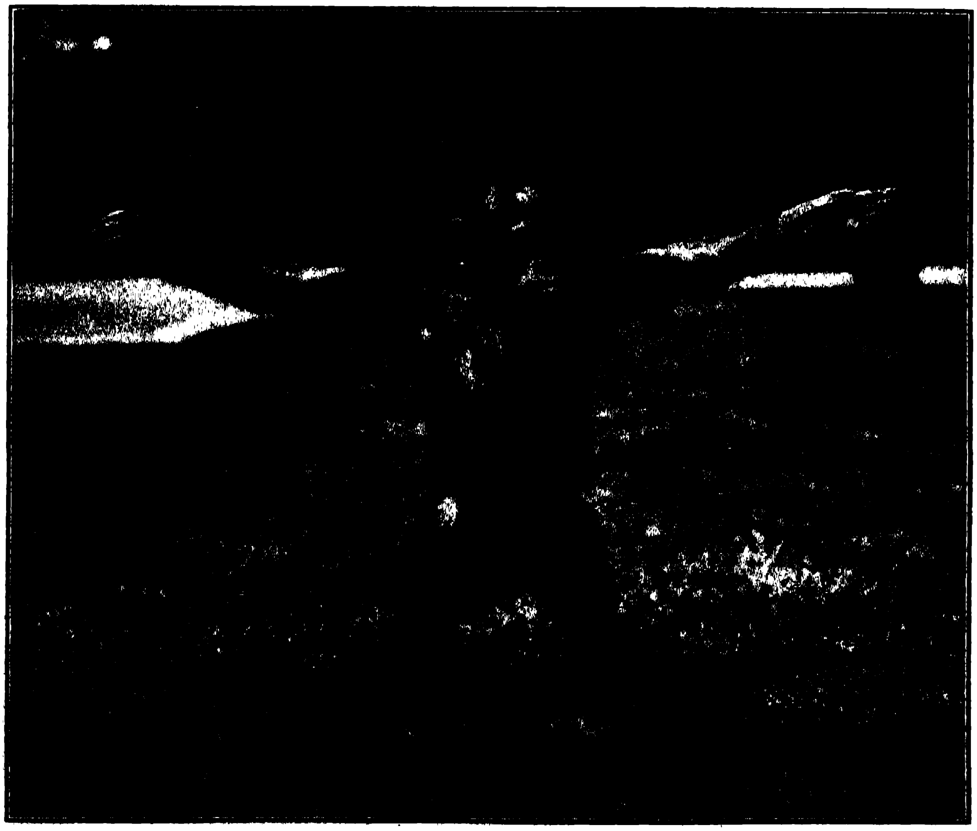


Fig. 6. The walking, juvenile Chimpanzee, balanced by the extended arms, with hooked fingers (angulodactyly), shortened legs. The arm stretch is less extreme than in the Orang and much less extreme than in the Gibbon. Courtesy New York Zoological Park.

FIG. 7. THE KNUCKLE-WALKING, QUADRUMANAL GAIT OF THE GORILLA, "DINAH," DUE TO THE PRONOUNCED ANGULODACTYLY. THE PROLONGED LIMB-SWINGING USE OF THE FINGERS PREVENTS THE OPENING OF THE HAND AND ENFORCES THIS KNUCKLE-WALKING PROGRESSION. COURTESY NEW YORK ZOOLOGICAL SOCIETY.

of Man's Kinship to the Anthropoid Apes." These tables are checked to indicate (a) substantially identical conditions, (b) nearness to man, (c) marked resemblance or approach, (d) intermediate conditions, (e) radical differences or contrasts, (f) occurrence as variants, (g) occurrence as vestiges, (h) normal condition. Summarizing the recent work of Tilney, Schultz, Straus, Keith, Landsteiner, Woolard and others, and the earlier work of Retzius, Hubrecht, Sonntag, McGregor, Selenka, Deniker, Pocock, Bolk, Reichenow, Huntington, Todd, Willis, Boas, etc., the conclusion is reached that "the evidence for man's kinship with the anthropoids and for arboreal derivation is now overwhelming," especially in the following characters: (1) general physiology: blood and chemical reactions, susceptibility to characteristically human diseases; (2) reproduction and development, all phenomena; (3) fundamental habits of social and family life; (4) in another class of characters, namely, the trunk and vertebral column, the fundamental relations of the limb arches to the trunk, such as the loss of the caudal vertebrae (tail), change of function in the tail muscle, shortening of the lumbar region, foetal proportions of the limbs and innumerable other foetal characters, the kinship is equally strong. The above physiological and organic differences are in large measure supported by adult axial and by foetal limb stages. (5) There are marked resemblances in the lips, mouth and throat, in the structure of the tongue, mouth glands and larynx, and (6) in the endocrine system, in the sense organs, the accessory points of hearing, in the eyes and vision, there is striking likeness between man and the anthropoid apes, as especially developed by the brain studies of Elliot Smith and

FIG. 8. THE SOLE OF THE FOOT OF THE GORILLA, "DINAH," SHOWING THE GREATLY ENLARGED AND SPREADING BIG TOE AND THE RELATIVELY SHORT, APPRESSED TOES. COMPARE WITH THE FOETAL HUMAN FEET (FIGS. 9, 10) AND NOTE GENERAL RESEMBLANCE. COURTESY NEW YORK ZOOLOGICAL SOCIETY.

of Tilney. (7) In brain and mentality, from the time of Flechsig, the strong points of superficial cerebral resemblance of the ape to man have been increasingly observed and have recently been extended in Tilney's studies of the central brain structure and tested by the remarkable psychiatry of Yerkes.

It will be observed by careful study of Gregory's kinship tables that *the majority of characters which establish the kinship of the anthropoid apes to man are primitive characters also possessed by a long remote, common anthropoid stem.* They subserve functions of reproduction, of the sense organs, of social and family relationship, of the central part of the skeleton, which are equally serviceable to anthropoid primates which may differ widely in locomotor structure and habit.

Let us therefore reexamine the anthropoid apes from the standpoint of bodily locomotion in its direct bearing upon life habits and upon all the psychic actions and reactions of the limbs, feet and hands, especially of the hands.

Influence of Bodily Locomotion

As to which anthropoid comes nearest to man Gregory's generalization from the hundreds of descent observations is as follows, in descending order:

Modernized man
Primitive man
Chimpanzee of the African forests
Gorilla of the African forests
Orang of the East Indies
Gibbon of the East Indies
Old World monkeys
New World monkeys
Tarsius
(Lemuroids, lemurs)

The known phylogenetic or ancestral relationships to each other of these various branches of the great order of Primates is shown in a chart after Gregory.

Habit is king, because function rules the locomotor organs and ultimately determines their structure, whereas the organs merely condition and limit the functions. We now enter an entirely new field of human or ape progress, which Gulick (1905) terms "habitudinal evolution." Such evolution in the locomotor organs results in what Gregory has aptly termed "habitus," or external form and appearance of relatively recent acquisition in contrast to the "heritage" of more profound and less conspicuous characters of remote, common ancestral origin.

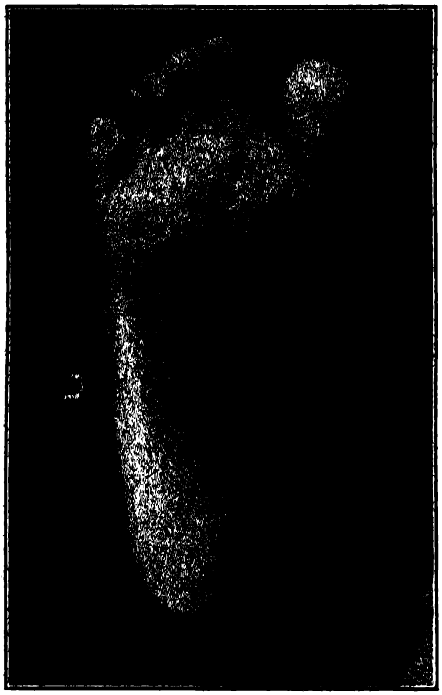
But the general adjectives "arboreal," "terrestrial" and "cursorial" do not fully classify or subdivide the *phases* of habit, of ground or of tree life. Analysis of foot and hand structure reveals the following kinds of primary and secondary adaptations:

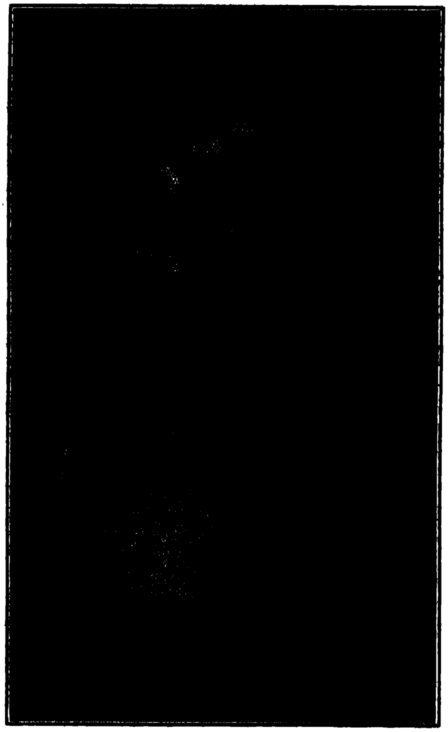
(1) Terrestrial insectivorous and carnivorous animals which seek or chase their prey in trees (*e.g.*, tree shrews, leopard, panther)
(2) Terrestrial herbivorous animals which seek food in trees (*e.g.*, squirrels)
(3) Terrestrial animals which seek defense in trees, ending in home building (*e.g.*, orang)

These habits result in the following progressive arboreal stages:

(a) Terrestrio-arboreal, carnivorous, insectivorous, herbivorous mammals
(b) Arboreo-limb-walking, *e.g.*, squirrels
(c) Arboreo-volant, *e.g.*, flying squirrel
(d) Arboreo-limb-swinging and brachiating, *e.g.*, chimpanzee, orang
(e) Hyper-arboreo-brachiating, *e.g.*, gibbon, tree-sloth
(f) Secondary arboreo-terrestrial, *e.g.*, chimpanzee, orang
(g) Secondary terrestrio-arboreal, *e.g.*, gorilla.

Recent man, as well as Stone Age man, including the now well-known Cro-Magnon, Neanderthal, Heidelberg, Trinil and Piltdown types, does not exhibit in limb structure or in hand and foot structure, so far as known, any of the essential arboreal adaptations, but on the hypothesis that man is descended from a tree-living ape type, embryonic and foetal reminiscences of former arboreal life should be apparent. The





FIGS. 9, 10. TWO STAGES IN THE DEVELOPMENT OF THE HUMAN FOETAL FOOT, SHOWING THE RELATIVELY ABBREVIATED AND WIDELY SPREADING BIG TOE. NOTE THE APPRESSED SMALLER TOES AS IN THE GORILLA. COMPARE FIG. 8. AFTER SCHULTZ.

most important effect of arboreal or of cursorial habit is shown in limb proportions, in the relative length of the arm and of the limb. But limb proportions differ widely in various arboreal types, as demonstrated by Morton[4] in his table of ratios. These ratios are discussed by Gregory[5] as follows:

ARM AND LEG LENGTH INDICES IN APES AND MAN

The contrast between the hyper-arboreal [ape] and the hyper-cursorial [man] types is beautifully illustrated in Dr. Schultz's drawing in which the fetal and adult stages of anthropoids and man are contrasted. This diagram is at the beginning of his paper on "Fetal Growth of Man and Other Primates."

[4] Dudley J. Morton: "Human Origin," *American Journal of Physical Anthropology*, Vol. X, No. 2, April–June, 1927, pp. 173–203.

[5] William King Gregory, letter to author, November 23, 1927.

(1) Arm length from head of humerus to ball of hand, in relation to length of trunk.

No recorded measurements are available giving the length of the arm extending only to the ball of the hand (as in the quadrumanal gait of the monkey), but a brief table (after Morton) shows the total length of the forearm in terms of sitting height. If the length of the torso (first dorsal vertebra to posterior end of ischium) is taken as unity, the combined length of the humerus and ulna is as follows:

In typical cursorial mammals (*e.g.*, dog)	40–46
In *Notharctus* (Eocene lemur)	49
In Lemuroids	60
In Old World monkeys	68
In Man	90
In Chimpanzee	97–100
In Gorilla	100
In Orang	118
In Gibbon	149

(2) **Leg length from head of femur to ball of heel, in relation to trunk.**

This measurement can not be given exactly because the head of the femur is not available for measurement in living animals, but close approximation to what is desired can be made by giving the total hind limb length (to great trochanter) in terms of sitting height.

In 1916 ("Evolution of the Primates," pp. 332, 335), I [Gregory] pointed out that such contrasts in indices are apt to be deceptive if they exhibit only the divergent end forms and lack the stem form from which both originated. In this case it seems probable that from the evidence of the brain and many other organs, the chimpanzee stands nearer to the stem forms than does the orang at one extreme or man at the other. The gibbon plainly is an offshoot of an earlier stage. This is well indicated in Schultz's diagrams. Doubtless in all such cases the critical question is not how much do the extremes differ but to what extent have both relative lengths and breadths been made over after a profound change of habits, such as the transition from the erectly-moving, arboreal, primitive brachiating stage to the hyperbrachiating stage (orang) on the one hand and to the long-legged, short-armed hyper-cursorial stage on the other.

The following indices were kindly collected by Dr. H. L. Shapiro, of the American Museum staff (letter to author, November 2, 1927):

(1) Arm (without hand) Relative to Length of Trunk

	Subjects exam.	Ratio
Man (Baden)	100	115.9
Neanderthal	1	115.4 (skeletal measures)
Chimpanzee	8	122.6
Gorilla	2	133.5
Orang-utan	5	160.2
Gibbon	29	188.8

Lower Arm Relative to Trunk

Man (Baden)	100	50.9
Chimpanzee	8	59.1
Gorilla	2	60.5
Orang-utan	5	78.4
Gibbon	29	97.8

Total Arm Length Relative to Trunk

Man (Baden)	152.7
Chimpanzee	180.1
Gorilla	188.5
Orang-utan	223.6
Gibbon	246.9

(2) Leg (without foot) Relative to Trunk

Man (Baden)	100	158.5
Neanderthal		158.6 (skeletal)
Chimpanzee	8	113.2
Gorilla	2	113.0
Orang	5	111.2
Gibbon	28	130.7

From these indices, derived differently from Morton's, I reach the following conclusions:

In both recent and Neanderthal man the measurement from the arm to the wrist or palm is 115 per cent. of the trunk measurement, whereas the hyperarboreal arm of the gibbon is 188 per cent. of the trunk measurement. Similarly, the total arm length in man is 152 per cent. of the trunk measurement, while it rises to 180 per cent. in the chimpanzee and 246 per cent. in the gibbon. The comparative leg indices are just the opposite: both in recent and in Neanderthal man the leg is 158 per cent. of the trunk, while in the orang the length is 111 per cent. of the trunk. The adaptive principle in these

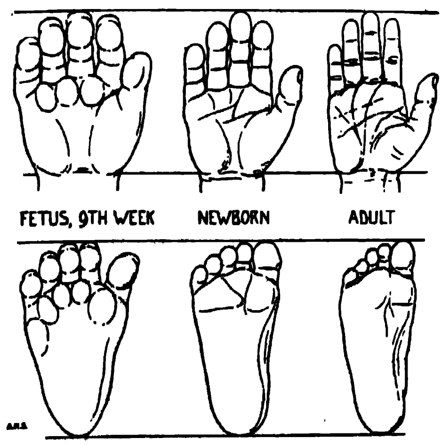


Fig. 11. Embryonic to adult stages in the human hand (upper row) contrasted with embryonic to adult stages in the human foot (lower row). After Schultz. Observe that in the foetus of the ninth week there is no trace of the slender or hook-like fingers of the anthropoid ape. Compare Fig. 12.

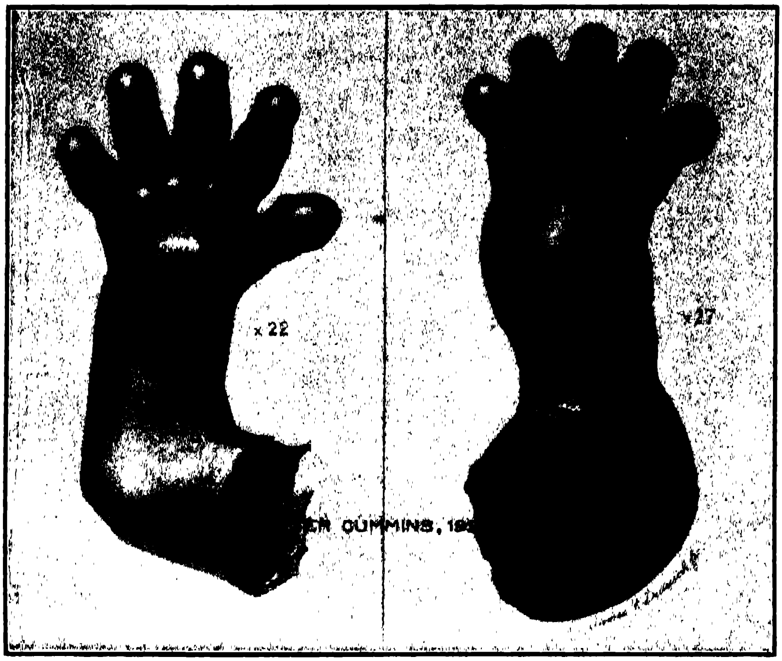


FIG. 12. EARLIEST SPREADING STAGE OF THE EMBRYONIC HUMAN HAND (LEFT) AND FOOT (RIGHT), GREATLY ENLARGED. AFTER SCHULTZ AND CUMMINS. OBSERVE THE WIDELY SPREADING FINGERS AND TOES AND THE ABSENCE OF ANY TRACE OF ANTHROPOID APE AFFINITY.

limb proportions is that as we ascend from the quadrumanal through the bipedal to the arboreal types of primates *the arms progressively lengthen and the legs retrogressively shorten;* on the contrary, when we descend from the arboreal through the quadrumanal to the cursorial type *the arms progressively shorten and the legs progressively lengthen.*

In the developing human infant, as clearly shown in the recent diagram of Schultz, the arms progressively shorten and the legs progressively lengthen. The human infant, therefore, in its early foetal stages has long arms and short legs, whereas in its late stages before birth it has arms and legs of nearly equal length. In this important respect the developing human being sustains the arboreal theory of human descent. In one of Schultz's valuable figures, however, it will be observed that the hands and fingers have been unintentionally elongated by the draughtsman, since the hand and fingers differ widely from the proportions shown in Fig. 11 (hand of the foetus of ninth week).

The developing human hand as illustrated by Retzius and more recently by Schultz does not appear to lend any support to the ape theory of human descent. From the earliest stages observed, the fingers are short and spreading, and at no stage do they give any evidence of the elongated hook-like form characteristic of all the anthropoid apes. They develop gradually in length and spread apart in preparation for their use in the crawling position of infancy, with relatively short, spreading fingers, rather than for the limb-swinging or brachiating function with closely appressed and elongated fingers. No one watching the marvelous flexibility and

the lightning-like innervation of the fingers of a great pianist like Paderewski or Horowitz, in which each finger and each joint move independently of every other, can conceive of the descent of the wonderful adult human hand from the brachiating type of the ape. It is rather derivable from the limb- or branch-walking and clinging type of hand of certain of the monkeys and lemurs.

Intensive Observations on the Limbs, Hands and Feet of Monkeys and Apes

With the rich resources in living primates of the New York Zoological Park Curator Raymond L. Ditmars, aided by Elwin R. Sanborn, has been photographing and closely observing the uses of the hand and foot in lemurs, monkeys and apes. The types especially examined are:

Lemurs
- Slow lemur of India
- Black and white lemur of Madagascar

Rhesus Monkey of India
Japanese Macaque
Pompadour Macaque of India
Potto of Africa.
Collared Mangabey of West Africa
DeBrazza Guenon of the Congo
Whitefaced Sapajou of South America
"Woolly Monkey," Lagothrix, of Brazil.
Woolly Monkey of Guiana
Saki Monkey of northern South America
Black Spider Monkey

These animals present all the phases of arboreal habit, from the slow-moving lemur and potto, which progress chiefly along the limbs and branches of trees, to the highly specialized and brachiating "spider monkeys," which parallel the gibbon in the power of rapid progression among the treetops. The limb indices and ratios of these animals have not been taken, but they indicate this progression to arboreal adaptation:

(a) Balanced length of fore and hind limbs
(b) Steady elongation of the fore limbs
(c) Static condition or reduction of the hind limbs
(d) Early limb-grasping power of the thumb (*e.g.*, Potto, Lagothrix, woolly monkey) sometimes retained
(e) Progressive reduction of the thumb (Ateles)
(f) Early limb-grasping power of the big toe (not elongated, *e.g.*, Potto)
(g) Big toe elongated and set apart (woolly monkey of the Guianas)
(h) Progressive elongation and syndactyly of the digits both of the hands and of the feet (spider monkeys).

Among the arboreal lemurs and monkeys of the Old World (Catarrhines) and of the New World (Platyrrhines) there is a great diversity in limb, hand and foot, owing partly to the survival of primitive limb-walking forms.

In the anthropoid apes *there is a strikingly uniform evolution into the highly specialized arboreal type known as limb-swinging or brachiating, invariably adaptive as follows:*

(a) Fore limb elongated in direct ratio to acquisition of hyper-arboreal habit
(b) Hind limb reduced in the same ratio
(c) Four digits of the hand directly elongated, appressed, with conjoined movement, *i.e.*, syndactyly
(d) Thumb actually and relatively abbreviated, with loss of grasping function
(e) Consequent final transformation of the hand into a hook, *i.e.*, angulodactyly
(f) Transformation of the foot into a hand by moderate elongation of the four main digits, and strong separation, development and grasping power of the big toe.

Thus the anthropoid apes are no longer quadrumanous, because the hand is completely transformed by losing its handlike functions, while the foot loses its footlike functions and is transformed into a hand. This adaptation is in widest possible contrast to the adaptation in the Bimana (the term originally applied to the human division), in which the hand is transformed into a super-hand and the foot into a super-foot, splendidly adapted to very rapid plantigrade, cursorial locomotion.

Accepting Dollo's dictum that evolution is never reversed, that lost organs are never regained, we do not conceive it possible that the brachiating anthropoid could reverse the whole direction of its evolution, regain its lost powers and diminished organs and set out in an entirely new direction into the bimanous pro-Dawn Man type.

McGregor's Notes on Tree Shinning and Erect Attitude in Apes and Man

The distinctively human powers of locomotion, of dexterous use of the hand and thumb, of bipedal and erect attitude, flash out here and there among the anthropoids as *vestigial functions*. It appears that in previous papers I have made certain misstatements in this connection, which I can best correct by quoting directly from my colleague, J. Howard McGregor, who writes, January 3, 1928:

You speak[6] of man "shinning up the tree by embracing the trunk with his arms and shins. "No anthropoid ape," you say, "displays this power. . . . *The ape must rise into the tree, not by the trunk route, but by the branches.*"

I wish you could have seen John Daniel 2nd[7] three years ago when Miss Cunningham, Captain Penny and I took him in a taxicab to a park in Newark. There was a number of quite straight trees, I should say from nine to twelve inches in diameter and with no branches lower than nine or ten feet from the ground. I was very much interested to see him rush rapidly up the trunks of these trees, very much as a boy would have climbed them, though of course, his arms being longer and his legs shorter, the knees seemed to project less than in the case of a boy. He did not exactly embrace the trunk with his shins, but placed the soles of his feet against it—very much like the men in the photograph from Lang which you publish. He seemed to enjoy climbing these trunks; there were several varieties of trees and he ran from tree to tree, climbing in all a considerable number—I should say certainly six or eight, at least. He would rush up a trunk out onto the branches and there he would swing. I remember in one case he let go a branch with his hands and swung head downward by his feet. On one occasion he hung from a branch with his hands and dropped to the ground as the small branch swung rather low.

Mr. Raven of the Museum tells me he has also seen *monkeys* in the East Indies climbing the smooth boles of trees very much as a man would climb.

Erect Attitude

I somehow gained the idea that you had stated that the earlier observers of the gorilla believed that it walked erect like a man, and that you gave Akeley some of the credit for disproving this. I have just been going over Du Chaillu's work and find him most emphatic in stating that the gorilla goes habitually on all fours, rising on the hind legs when he attacks—which would be quite necessary as the arms are used as weapons. I think the rather prevalent idea that the gorilla habitually walks like a man is simply a popular notion—probably based on nothing more substantial than the illustrations in Du Chaillu's work, all of which show the animal at the time of attack. The statement is made in Richard Owen's earliest papers on the gorilla that it goes on all fours. This is probably based on Savage's descriptions. On looking up Savage and Wyman's article published in the *Boston Journal of Natural History*, 1847, I find it says of the gorilla (page 423):

"The gait is shuffling; the motion of the body, which is never upright as in man, is somewhat rolling or from side to side. The arms being longer than the chimpanzee, it does not stoop as much in walking. Like that animal it makes progress by thrusting its arms forward, resting the hands on the ground and then giving the body a half-jumping, half-swinging motion between them. In this act it is said not to flex the fingers, as does the chimpanzee resting on the knuckles, but to extend them thus making a fulcrum of the hand. [This last statement is of course an error.—McG.] When it assumes the walking position, to which it is said to be much inclined, it balances its huge body by flexing the arms upward."

In my observations on John Daniel 2nd, I noticed that he very frequently rose to his hind legs, often taking a few steps in this position; and of course in beating his chest he always stood fairly erect on his hind feet. It was noticeable that sometimes when in a hurry he moved the arm and leg of the same side together, like the racking or pacing gait of a horse. This was by no means his habitual gait,

[6] "Man Rises to Parnassus," p. 180; fig. 82.
[7] Young gorilla trained by Miss Alyse Cunningham.

but I recall noticing and commenting on it. He also tended to keep one side in advance so that he seemed to run sideways. Miss Cunningham (or it may have been her nephew) told me that John Daniel 1st also had this oblique method of running.

I have just returned from a week in Sarasota, Florida, where, with Yerkes, I spent a great deal of time examining and photographing the female mountain gorilla "Congo." I noticed her gait with special care, and in no case did I observe this pacing gait. One hand and the opposite foot were always advanced at the same time, so I am inclined to think that the occasional pacing gait which I observed in John Daniel 2nd is not common. I had not observed it in either of two very young male gorillas which I have seen recently. These were babies approximately one year old. I may add that, on one occasion, I saw "Congo" rise to her hind feet and walk in erect position a distance of about ten or twelve feet to the opposite side of her large outdoor cage. I was fortunate in securing a number of photographs and also 16 mm. moving picture film of the gorilla in Florida.

Reduction of Thumb

I also feel that you rather exaggerate the reduction of the thumb in the anthropoid apes. Of course it is somewhat smaller than in man, but seems relatively smaller than it is because of the great elongation of the palm and fingers in the anthropoids. In some of the South American monkeys, even completely *arboreal* types such as *Lagothrix* (the woolly monkey of the forests of Brazil), the thumb, though not opposable, is quite as long as in man. This seems rather strange, because in *Ateles*—the spider monkey—which is undoubtedly very close to *Lagothrix*, the thumb reaches its maximum reduction. You state[8]: "All arboreal mammals are practically thumbless." Perhaps you mean *opposable* thumbs, but many Old World *monkeys* can perfectly oppose the tip of the thumb and the tip of the index finger. I have made numerous observations on these points. I hope soon to have motion picture films to illustrate the anthropoid method of climbing trees, and also the use of the thumb. I have a film (from Ditmars) showing a young chimpanzee using needle and thread, holding the needle as mentioned above.

[8] "Man Rises to Parnassus," p. 180.

Conclusion

This concludes our present survey of the influences of bodily locomotion in separating man from the monkeys and apes. It is clear, in so far as the evidence in this connection is concerned, that the theory of arboreal ancestry of the human type is well established, both by the proportions of the limbs and possibly by the inturning of the soles of the feet, also to a less degree by the spread of the big toe. It is possible that the intra-uterine abbreviation of the hind limb and even the inturned soles of the infant feet are an adaptation to the very confined position of the unborn infant.

On the other side of the case, the structure of the foetal and infant hand does not support the brachiating ape theory. The structure and proportions of the limbs, the hands and feet, taken altogether, do not harmonize with the brachiating ape theory, but, to my mind, suggest rather the taking off of the human stock from the second progressive arboreal stage, namely, arboreo-limb-walking stage (p. 393, b). Derived from this stage, the pro-Dawn Man would conserve all the potentiality of future application of the hand to flint-making and, ultimately, to the arts and industries by which man has arisen.[9]

[9] The sixth in a series of papers on human evolution, the preceding five having been presented as follows: (1) "Fundamental Discoveries of the Last Decade in Human Evolution," New York Academy of Medicine, April 7, 1927; (2) "Recent Discoveries Relating to the Origin and Antiquity of Man," American Philosophical Society, April 28, 1927; (3) "Recent Discoveries in Human Evolution," Medical Society of the County of Kings, May 17, 1927; (4) "Recent Discoveries Relating to the Origin and Antiquity of Man," *Palaeobiologica*, Band 1, December 7, 1927; (5) "The Influence of Habit in the Evolution of Man and the Great Apes," New York Academy of Medicine, December 16, 1927.

GROWING OLD AND THE SEARCH FOR AN ELIXIR OF LIFE[1]

By the late Professor A. C. EYCLESHYMER

IN youth, the elastic, sturdy and vigorous body adapts itself most completely to its surroundings. We find, as Lubbock has said, that "every sort of beauty has been lavished on our allotted home; beauties to enrapture every sense, beauties to satisfy every taste; forms the noblest and loveliest, colors the most gorgeous and the most delicate; odors the sweetest and subtlest; harmonies the most soothing and the most stirring." The heart throbs, the senses quiver, and the brain overflows. We are in fullest appreciation of all nature.

As the years pass by, the body loses in elasticity, strength and vigor. The eye is not s okeen, nature's colors are not so bright; the ear is not so acute; we listen more intently to catch distant sounds; memory is not quite as reliable; reason not quite as trustworthy; the love of both work and pleasure is a little less; a few clouds appear on the horizon. We scarcely know that the summer of life is passing and that old age is approaching so quietly and gently.

The body becomes bent, rigid and fragile; the teeth decay, the hair falls out, the dried and wrinkled skin shows dark varicose veins; memory and reason are fast going; ambition and patience give way to despondency and irritability. The cold, dark clouds of life's winter are gathering; the ghastly image of old age is ever near and haunts us through the long restless nights. The scriptural formula "three score years and ten" makes the seventieth birthday for many persons the saddest of all.

As the great Hogarth's life was drawing to a close he painted a most remarkable picture. On the canvas he represented a broken bottle, a cracked bell, an unstrung bow, the signboard of a tavern called "The World's End" falling down, a shipwreck, the horses of Phoebus lying dead in the clouds, the moon in her last quarter, and the world on fire. "One thing more," said Hogarth, "and I am done"; he added to the picture a broken palette. It was his last work and it represented the last days of human life.

The human heart loves life in its fullness and yearns to prolong the period of youth. It recoils from the struggle with old age and ever tries to exclude the thought which brings but sorrow and pain. All the ideals, the dreams, the visions of immortality center around the conservation or restoration of an active body or mind, or both. No one has ever pictured the continuation of senile processes in the life beyond and through eternity.

The question of growing old is one of such moment that it has attracted thinkers of all ages. Patriarchs and prophets, philosophers and theologians, magicians and scientists have each tried to find some means of restoring youth or preventing old age.

Biblical narrative teaches us that there was a "tree of life" in the Garden of Eden. After Adam had eaten of the fruit of the "tree of knowledge," and thereby knew good and evil, the Lord sent him from the Garden "lest he put forth his hand and take also of the tree of life, and eat, and live forever." For centuries the idea prevailed that there must be, somewhere, a tree which was

[1] This manuscript left in incomplete form by Dr. Eycleshymer on his death has been prepared for publication by his friend, Dr. E. P. Lyon.

intended by the Creator to preserve man from disease and death. The search for the tree of life was carried far and wide. Some thought it to be the aloe, others the cedar, still others the amber. The dark hellebore, the crocus and other herbs, their balsams and infusions also were thought to give new life.

The stars next attracted man. It was commonly believed, by the Egyptians and long after them, that the constellations and planets possessed either good or evil qualities which were given to those born under them. Astrology appealed not only to the ignorant but to the educated. Priests, poets, philosophers and physicians devoted much time to the casting of horoscopes. They could read in the heavens, so they thought, the day of birth, the peculiarities of life and the day of death. If it were possible to foretell the day of death, were it not possible to carry a life beyond the fixed date? This the astrologer attempted by locating the star causing the disease, and then invoking a beneficent star to annihilate the effects of the malignant one.

Since the metals were thought to be intimately associated with the planets, it was natural that the astrologers should advise the wearing of amulets or figures which had been cast, stamped and submitted to the influence of the stars, thereby imparting to the metal a subtle charm. Some talismans protected from fire, prison, wild beasts and the like; others were struck for the various diseases and finally, by adroitly mixing, talismans were cast which kept away all evil.

When astrology lost its influence over thinking people, through the discovery of the Copernican system and Newton's laws, alchemy became its successor.

Alchemy was based upon the assumption that somewhere among nature's hidden treasurers there was a substance which would produce gold from metals which contained no gold. The alchemists were not slow in realizing that so much gold would be of little value unless the life of man were long enough to spend it. Renewed efforts were made to find an elixir which would prevent disease, prolong life and restore youth. To what extent the Spagyric writers considered the philosopher's stone and the elixir of life identical is a question. By some, the elixir of life was said to be like sea-water; by others, like port or sherry wine; still others thought it to be an invigorating paste. By the greatest number it was thought to be liquid gold.

The sun, for ages, had poured its limpid golden rays upon the earth and had given to the earth power to bring back life. Each winter death fell upon the earth, but with the return of spring life came again. It was thought that the sun must be the source of life. Some went so far as to place open jars in the sunshine during the summer and then collected the dust in the autumn; this dust they regarded as the real solar powder which would give new life. Others thought that the sun's rays went deep into the earth, and when a careful search revealed mineral gold, it was believed to be the substance in which the life-giving rays were held fast.

As early as the eighth century, Gerber compounded a red elixir from gold, which he claimed would rejuvenate old people. The alchemists of the twelfth and thirteenth centuries became divided into schools, the one seeking to transmute the base metals to gold, the other trying to find that special potion which would cure all ills, preserve youth and prolong life.

The transmutation of metals later became the chief aim of alchemy, the love of life being gradually replaced by the love for gold. Moreover, it was easy to show an apparent transmutation of metals by clever tricks; but no deceit could show the return of youth in the aged.

The last serious attempt, on the part of the alchemists, to discover or compound an elixir of life was in the early part of the sixteenth century when a Swiss alchemist, commonly known as Paracelsus, who had studied deeply in chemistry, announced that "man is a chemical composition; disease causes an alteration in this composition; it thus is necessary to use chemical means to combat disease." Paracelsus thought that he had discovered how the vital spirit was formed and even went so far as to state that he could create men in an alembic. He burned the books of Galen and proclaimed that there was no disease he could not cure, nor life he could not prolong. So great became his notoriety that people flocked from all parts of the continent to be treated. It was later found that his "great elixir" or "vegetable sulphur," as it was called, was nothing more than a mixture of the extracts of aloe, myrrh and saffron.

In the days of the patriarchs, the idea arose that blood was the life fluid. Thus we read, in Deuteronomy, that flesh may be eaten but not blood. "Only be sure that thou eatest not the blood, for the blood is the life; and thou mayest not eat the life with the flesh." In ancient Rome, before the vast gathering in the Coliseum, the bleeding gladiator exclaimed: "Ave, Caesar, morituri te salutant!" As he thus saluted Nero, Roman women suffering from epilepsy rushed to the arena to drink the blood as it gushed from the fatal wounds. As time passed the blood was regarded by an increasing number as the life carrier, but the scriptural admonition kept man from using it to any extent until the time of Louis XI who, it is said, made real the fable of the vampire by frequently drinking the fresh blood of children as a means of rejuvenating himself.

About the middle of the seventeenth century, the art of transfusing blood arose. This was done by opening the vein of one animal and, by means of a tube, carrying over the blood into the vein of another animal. This was tried on horses and it was said that by transfusing the blood of a young horse into that of an old and decrepit one, the old horse became a colt again. It was also said that courage could be transfused into the timid by using the blood of the wild, and that the wild could be subdued by using the blood of the timid.

In 1667, Denys, of Paris, transfused about a pound of calf's blood into the veins of a maniac. This was twice repeated. The patient died and his wife brought suit against Denys. This resulted in transfusion being prevented by law, and for more than a hundred and fifty years this method was not practiced. When revived by Blundell, Diefenbach and Magendie, it was again fraught with dangers and was but little used.

Later, it was found that the blood of an animal undergoes dissolution when the blood of another species is transfused. The researches of Ehrlich and Morgenroth on haemolysis have given us a fairly clear understanding of this process.

Another supposed panacea, which must have been of very ancient origin, was based on the belief that the flesh of the serpent himself must be an antidote against his own death-dealing venom. In the early part of the ninth century Avicenna tells us that "the flesh of the serpent when duly prepared forces all the humors to depart. It also prolongs life, maintains the faculties of the body, and preserves youth." Roger Bacon, several centuries later, expressed great faith in viperine flesh which, however, he observes, should not be taken except when the sun ascends.

Among the older methods adopted for the prolongation of life was the Gerocomic which held that the primitive life-giving substance was to be found in its purest state in the breath of innocents. Thus the custom arose of breathing in

new life and vigor through close contact with the young. David, King of Israel, employed this method to prolong his life. Hermippus, who is said to have conducted a girls' school in Rome, thought that by inhaling the pure breath of the young maidens he had prolonged his life a number of years. Even in the latter part of the eighteenth century, Boerhaave assures us that by bringing the old in close proximity to the young the old are greatly invigorated.

During the latter part of the eighteenth century, the French capital was thrown into a state of great excitement by Frans Mesmer, who conceived the idea of making magnets which he sold as a remedy for toothache, neuralgia, rheumatism, etc. Being successful in this venture he went a step further and maintained that great magnetic force emanated from his person. He brought forward many people who proclaimed his healing power and who were firmly convinced that at will he could dispense pleasure or pain to mankind.

One of Mesmer's disciples wrote of his powers as follows:

> Behold a discovery which will bring invaluable advantage to mankind and eternal fame to its author! Behold a general revolution! Other men will inhabit the earth; they will be checked in their careers of life by no weakness and will be acquainted with our evils only by tradition; mothers will suffer less from pains of childbirth, and will bring forth stronger children who will possess the activity, energy and courage of the old world. Animals and plants, alike, susceptible to the magnetic virtue, will be free from disease; flocks will more easily increase; the productions of our forests will have more vigor; the trees will produce more beautiful fruit. The human mind in possession of this agent will perhaps present to nature effects still more wonderful. Who can know how far its influence may extend?

A commission was soon appointed by the French Academy of Science, under the direction of Dr. Franklin, to investigate the claims of Mesmer. The mystery was solved, the false claims discounted and all that remained was "animal magnetism," or, as we say, hypnotism.

The wanderings of Ponce de Leon in quest of the fountain of eternal youth, the transformations of the Navaho's revered goddess who grows old and at will becomes young again, the eating of powdered mummies, self-inflicted tortures, burning of witches, all belong in the same general category. Folk-lore and history are filled with attempts to restore youth, prolong life, rid the body of disease and drive out evil spirits. The earth, the air and the heavens were thought to be the abiding places of illness. Old age, disease and evil were thought of as entities restlessly flitting hither and thither, hovering over and descending upon mankind either by chance or at the behest of enemies, witches, demons or angry gods. Pleadings and prayers, infusions and balsams, extracts and excrements, talismans and magnets, ding-dongs and drums, dances and contortions, beatings and burnings were among the remedies, gentle and harsh, which were used to drive them away. The administration of these remedies was in the hands of priests, poets, philosophers, magicians, physicians and mobs. Disease was not understood, its real causes were unknown. Over the entire field of medicine there hung a dense cloud of mysticism.

It should not be inferred that the search, carried on during all these years, had been fruitless. Indeed there was a great residuum of observations which even to-day is undergoing winnowing and sifting in the hands of medical science. Moreover, the foundation of modern medicine had been laid through the work of Hippocrates, Aristotle, Galen, Vesalius and others. Above all, the belief has steadily grown that an elixir of life could not be found.

About the middle of the eighteenth century, scientific inquiry was begun with a view of ascertaining the maximal age which man had actually attained.

Haller, the great physiologist, stated that there were many well-authenticated instances in which man had attained an age of about one hundred and fifty years. James Easton, in the closing years of that century, published the names of seventeen hundred and twelve persons who lived for over one hundred years. Among these were fifty who had lived about 150 years; five 160, and two upwards of 170. There are doubtless many errors in Easton's records, as Thoms has pointed out. The case of Peter Torton, of Temesware, Hungary, who is said to have died at the age of 185 and that of John Roven at 172 and his wife at 164 may be ascribed to the overzealousness of the town to increase its population. We have, however, the testimony of most trustworthy men that Thomas Parr attained a very old age, possibly 152 years, as claimed. Harvey, who did the autopsy, was inclined to believe that the age given was nearly correct. The account of Henry Jenkins, who reached the century and half mark, as reported by Dr. Robinson, was accepted by the Royal Society and published in the "Philosophical Transactions" in 1696.

There is no published compilation of the number of centenarians who died during the nineteenth century. Here and there are suggestions which lead us to infer that the number must be considerable. In France statistics show that nearly one hundred and fifty deaths occur annually of people who have lived beyond one hundred years. In England and Wales the deaths of about one hundred annually are reported. The census of 1900 records three thousand five hundred and four centenarians living in the United States, while that of 1910 gives three thousand five hundred and fifty-five. The census of 1920 records 895 deaths of those who lived beyond one hundred years. At present it is not at all unusual to see the deaths of well-authenticated centenarians recorded in our daily papers.

In the latter part of the eighteenth century, the eminent naturalist, Buffon, undertook a study of life cycles of various animals as compared with their growth periods with the hope of obtaining facts which might throw new light on the life cycle of man. He concluded that most animals live six or seven times as long as it takes them to reach maturity. Flourens later worked over the same ground and claimed that growth ceases when the epiphyses become united with the bones. This union, according to Flourens' data, takes place in the dog at two years, in the lion at four, in the horse at five, and in man at about twenty. The normal life cycle of the dog is from ten to twelve years, of the lion twenty and of the horse about twenty-five or about five times the duration of growth. Accordingly, man ought to live about one hundred years.

Later investigations show that in man this union often does not take place until twenty-five, so that the normal life cycle from the standpoint of comparative longevity should be something over one hundred years. The evidence gathered from all sources seems to show that scientists have not widely erred in assuming that man should have a normal life cycle of not less than a hundred years. That he frequently has reached a considerably greater age is beyond question.

Many attempts have been made, during the last two centuries, to ascertain some of the factors which have conduced to longevity, such as geographical location, mode of living, diet, etc. From the study of the lives of nearly two hundred centenarians we gather but little. As to location, there are some differences. Eastern Europe has furnished more than Western Europe, although of a lower grade of civilization. In Western Europe, Greece has furnished a large number, while Switzerland has had but few. As to mode of living, the great majority came from those who led simple lives;

the agricultural classes furnished an exceedingly large proportion. As to diet, some ate one meal per day, others four or five. A few ate large quantities of food, the greater number a small amount; some lived entirely on vegetables, others to a great extent on animal foods. A few indulged in alcoholic drinks; others were total abstainers; most were temperate.

Hofmann, the physiologist, after reviewing all the work was unable to isolate the factors conducing to longevity. The best rules which he could offer were these: "Excess should be avoided in everything; old habits should be respected; pure air should be breathed; pure food should be taken; food should be adapted to temperament. Keep the heart light, the mind content and the conscience free." It should not be forgotten that senescence is in no small degree a state of mind as well as a condition of body. The physician's serious mien, his dubious shake of the head, and the confidential whisper, "You know, he is over seventy," have often lessened both happiness and life.

Science had well-nigh relinquished the hope that a panacea might be found when in 1880 the Society of Biology in Paris was astounded by the announcement of the well-known physiologist, Brown-Séquard, that he had discovered an elixir of life. It was and is a well-known fact that the atrophy or removal of certain glands such as the thyroid and the spermatic glands produces mental and physical debility. Brown-Séquard asserted that the weakness of old people depends, to some extent, on a natural series of organic changes but largely upon the gradually diminishing activity of these glands. Led by these postulates, he made an elixir from the seminal glands, the seminal veins, and the seminal fluid, which when injected beneath the skin had wonderful effects on a large number of experimented animals. Also he, in his own person, experienced a remarkable return of youthful activity, after its administration. Dr. Variot, of Paris, treated a number of aged people with the elixir and, although they were wholly unaware of its use, they were markedly rejuvenated. The use of the elixir spread like wild fire, physicians clean and unclean began to give hypodermic injections of the elixir and blood poisoning often followed. The results were not permanent. The elixir became capital for the charlatan, the merry-andrew, the cartoonist and even the vaudevillist.

Around the sex glands have centered all sorts of speculation and some experimentation. Our best deductions are that energy, both muscular and mental, are at highest tide during the period when the sex glands are most active, and conversely muscular and mental activity decline as these glands become less active. The experiments of Steinach, Voronoff and others indicate that a transplantation of active glands temporarily rejuvenates. Some twenty years ago, Dr. Goheen and the writer found that spermatozoa from the young rat when injected into the peritoneal cavity of an old rat increased the period of motility of the old rat's sperm. But the stimulus lasted only for a short time, following the injection.

From the evidence at hand, one would probably not go far afield in predicting that the day is not far distant when the gland jag will again be placed in the same category as the corn whiskey jag.

Brown-Séquard was the last scientist to cherish the hope of finding a panacea for old age. The next efforts in this direction were the attempts to find a single remedy for a group of diseases. This is well illustrated by the work of Metchnikoff, of the Pasteur Institute, who attempted to show that the large intestine, including the caecum, was evolved as a reservoir so that animals could retain large quantities of fecal matter and thus could run long distances without inconvenience. Man has inherited this useless

structure. This author cites many physiological experiments to show that there is no absorption of food materials in this part of the bowel, and that the mucus secreted is best interpreted as a lubricant. The accumulation and retention of fecal matter serves as a nidus for general fermentation and putrefaction and especially butyric fermentation which, in turn, gives rise to a number of diseases.

In order to lessen these processes and especially to neutralize the butyric fermentation, Metchnikoff says it is necessary to set up some counter process. Experiments show that one of the most effective of these is lactic fermentation. To induce this through simple means the author advocates the drinking of quantities of sour milk. It should not be inferred that Metchnikoff claims this as a panacea. He is careful to limit its use to the prevention of those diseases which result either directly or indirectly from intestinal autotoxins.

Efforts of a similar nature, that is, to find remedies for groups of diseases, are to be found to-day in the emphasis which is being placed on the so-called endocrine glands. Some maintain that senility is an epoch of ductless gland insufficiency. We know that the thymus gland is associated with the period of most active growth and then gradually disappears. The thyroid and pituitary glands are intimately associated with dwarfism and giantism. Horsley thinks the conservation of the thyroid gland is an essential for long life. We know something of the functions of the spleen and adrenal; less of the tonsil and corpus luteum and prostate.

The various interpretations of one member of this group—the so-called pineal gland—or are illustrative of our imperfect knowledge of the other members. The pineal gland to-day is believed to secrete some constituent of the cerebrospinal fluid. Yet we do not actually know that it secretes anything. Descartes thought it to be the seat of the soul; later when the brain-sand was found, the idea arose that this sand was ballast for effervescent dispositions. Then came the suggestion that the pineal body controlled waking and sleeping; then that it is an organ for the perception of temperature; then an organ in which the sense of return or homing is located; then the seat of a sixth and unknown sense; then a median or third eye; and finally a pair of fused embryonic eyes. All of which serves to emphasize the fact that endocrinology is a most fruitful field for investigation!

In recent years science has begun the study of old age from the standpoint of structural changes in the organs, tissues and cells. All know that the bones are more brittle and more easily fractured in the aged. This is due to the bones having become more calcareous. In the same way, the arteries undergo striking changes. The saying that "a man is as old as his arteries" is well founded. The arteries in old age become thickened, hardened and lessened in caliber from fibrinous and calcareous deposits, producing the disease called arteriosclerosis. This is most easily detected in the large blood vessels, but all, even the most minute capillaries, undergo the same gradual change.

This degeneration of the blood vessels results in a decreased supply of blood to all parts of the body. The blood supply to the brain is diminished, its nutrition is lessened, and its functions thus impaired. The vigorous brain of middle life gives way to the feeble intellect with its loss of memory and confusion of ideas so characteristic of old age. Not only is this true of the brain but the nerves themselves show a decrease in activity. The activity of the sympathetic system declines. The spinal nerves, which have to do largely with feeling and motion, conduct impulses less readily. The lessened blood supply to the stomach and other parts of the alimen-

tary system results in decreased powers of digestion and absorption with a corresponding decrease in nutrition. The elimination of waste materials is lessened so that such structures as the kidneys may become poisoned by their own secretions.

Since in the further presentation the problem must be considered from the standpoint of changes in the cellular elements, let us think of a drop of blood which contains many millions of cells. These cells are of two kinds, the red and the white. There are some millions of the red corpuscles and some hundreds of thousands of the white corpuscles in each drop of blood. These latter have the form, when they are killed and stained for microscopic examination, of irregular stars. In life they change their shape by their own inherent quality. The substance of these little stars is called protoplasm. Each of these stars or cells has at its center a little ball which is called a nucleus.

When disease-producing bacteria have gained entrance to the body, a great army of these white cells, which ordinarily are floating in the blood, crowd through the walls of the blood vessels and hasten to the spot where the bacteria are located. They immediately engage in conflict with the bacteria and consume them. By special staining we can determine the number of bacteria which each white blood corpuscle is able to devour. Thus we have a health index as far as these cells are concerned.

These white cells of the blood usually attack only a foreign foe, but at times they turn upon their fellows, the special cells, which they have hitherto protected, and destroy them. This point is forcibly illustrated by a well-known change which occurs in the animal kingdom. All of us know that the common pollywog or tadpole changes in some way into a frog. The most obvious external changes are the appearance of legs and the disappearance of the tail. This latter change is due to the fact that an army of white blood cells "marches" into the tail and devours the other cells which form it.

We know little of these white blood cells and their work in the body; they are always present in inflammation and when wounds are healing. Some have maintained that these cells in some way stimulate dormant cells into activity. They seem to play an important part in both constructive and destructive processes. Scientists have tried to find some means of controlling the activities of these cells and some progress has been made in that Metchnikoff some years ago announced the discovery of a special serum which retards their activities, but how to increase their activity is a problem as yet unsolved.

Roux, the celebrated anatomist at Halle, some years ago pointed out that the highly specialized cells of the body, such as the gland cells, muscle cells and nerve cells, are in constant struggle with a great group of connective tissue cells.

These cells, like the white blood corpuscles, belong to the simple or wandering type. Metchnikoff confirmed and extended these observations and says: "In growing old, the same condition is always present: the atrophy of the higher and specific cells of a tissue and their replacement by a lower type. In the brain, nerve cells disappear; that is to say, cells which subserve the higher functions such as intellectuality, sensation, control of movement, are replaced by cells of a lower type. In the liver, the hepatic cells, of great importance to the nutrition of the organism, yield to the simple cells. In the kidneys, the simple cells invade and block the tubules through which the elimination of waste matter is accomplished. In the ovaries, the ova, the specific elements which serve to propagate the race, are similarly eliminated and replaced by simple cells. In other words, a conflict takes place in our bodies between the higher cells and

the simpler or wandering cells of the organism, and the conflict ends in the victory of the latter." Thus it would appear that one means of deferring old age would be to strengthen the special cells of the organism and to weaken the aggressive capacities of the simple cells. Metchnikoff warns us that this is not presented as a definite, but as a possible solution of the problem, and is offered for consideration like many other hypotheses on scientific questions.

The changes occurring in the special cells of the body, as it passes from the stage of greatest to that of least activity, are not easily interpreted. In the first place, most of the cells of our bodies do not remain for the entire life cycle but are frequently cast off and replaced by new ones. But this is not the case with some, such as the nerve and muscle cells, which live as long as the organism maintains its integrity. The changes in the cells of the spinal ganglia, which belong to those nerves carrying sensation, are very striking, as shown by Hodge and others. As they grow old, they become smaller, their nuclear material diminishes, and the protoplasm becomes vacuolated. It is well known, too, through the discoveries of Nissl and others, that the active nerve cells, both along the spinal cord and in the brain, possess bodies which are considered as stored-up food material. Marenescho and others have shown that these bodies are greatly diminished in both size and quantity in old age.

The writer's studies, on the structural changes taking place in the growing old of muscular tissue, show that in the young and growing muscle cell a unit of nuclear material is in physiological equilibrium with two or three units of protoplasmic material, while in the old muscle cell, when growth has ceased, a unit of nuclear material is in physiological equilibrium with twenty or thirty units of protoplasm. When an old muscle cell is partially destroyed its destroyed portion can be replaced only when nature restores the equilibrium of youth. Minot believed that old age is a phenomenon which makes its appearance in childhood. "The nucleus atrophies from our youngest age to old age, it continually diminishes in volume, whereas the protoplasm becomes more abundant. In the perpetual consumption of the nucleus is revealed the reason of our getting old and dying."

Structural changes as indicated in dead and artificially stained materials are but crude indices of far more subtle changes. Biophysics teaches that heat, light, electricity, osmosis, pressure, etc., profoundly modify processes. Biochemistry teaches that the rates of protein, carbohydrate, fat metabolism and the action of the precious accessory vitamins are all definitely related to growth. The mysterious hormones, which correlate the activities of the sexual organs, the mammary glands and the thyroid gland, lead us into an almost unknown field. Way back in the earlier stages of individual life, certain exciters or tonines speed up cell division in certain groups of cells. This is visible in the formation of the blastopore, neural folds, the extremities and many other structures. If we press our inquiries back to the starting-point of the individual—the fertilized ovum—that marvelous vehicle which carries the parental qualities on into the offspring, we are in the presence of a microcosm, an almost unknown world, whose materials, potentialities and forces baffle the human mind. Until we know the materials and forces operating in some one living cell at some one time in its life, we shall be unable to evaluate the many factors which modify the life cycle of the organisms.

Not only must we push our inquiries further and further into this invisible world, but also we must increase our efforts in other lines. Through the avenues of empirical medicine and sanitary science, the expectancy of life has

been greatly increased. According to our best information, the average span of life was increased about four years during the seventeenth and eighteenth centuries, about eight years in the first three quarters of the nineteenth century and about sixteen years since 1875. While we have thus made much progress, we still lack information in easily accessible fields.

We keep the records of trotting horses and hunting dogs with great care and search back, for generations, to find the strong and weak points that we may, through a careful observation of the laws of heredity, accentuate the good and eliminate the bad. We heralded, with admiration, the work of Luther Burbank in making new and better fruits, through a careful study of the methods of perpetuating the desired qualities, which are found here and there in the parent fruits.

But the study of man, with a view of preserving and accentuating, in the offspring, the sterling qualities found among the ancestors, has not received serious consideration. Yet we know that heredity is one of the chief factors in longevity. There should be some means of recording the physical condition of each individual at frequent intervals. Every physician should be required to send to some bureau the precise data regarding his personal findings in the diagnosis and treatment of each disease, and such data should be placed, at once, in the hands of the physician who next comes in contact with the same patient. We could, thereby, anticipate many diseases and prevent or cure them in their incipient stages. We thus could obtain information as to the sequence of diseases. We know that measles predisposes to tuberculosis; rheumatism is often the forerunner of heart disease; scarlet fever of kidney trouble. By the collection and study of a great body of data we might be able to ascertain what effects, if any, the excision of organs and the administration of drugs have upon body functions, and whether they predispose toward other diseases. It may be said that the use of the statistical method in studying the problems of disease and old age has only begun.

Science makes tardy progress in the prevention and cure of disease because she is shown but little favor. It is not difficult to obtain millions of dollars for good roads; the improvement of rivers and harbors; the extension of commerce; the fostering of agricultural interests; the enlargement of army and navy. Yet, it is extremely difficult to obtain adequate funds to develop the vitalizing force for all these—human efficiency.

The trouble is, mankind has not as yet full confidence in medicine. Masquerading, under her name, are thousands of quacks and charlatans who bring her into disrepute. Quackery, which is outside the medical profession, is a great evil, but its consequences are not comparable to that which is inside. Nothing is so much needed in medicine to-day as apostles of sincerity—of stern and uncompromising animosity to all forms of quackery, both without and within the profession. How refreshing such frankness as that of Ambroise Paré: "I tend him, God cures him."

Again, when medical science is confronted with common diseases, such as whooping cough, measles, scarlet fever, pneumonia, cancer, paralysis and mental disorders, she, time and again, shows her weakness. Her strength, however, is seldom brought prominently before us. We are not impressed by the diseases we do not have.

Were the discoveries of medical science taken from us, one by one, until we returned to the condition of the middle ages, we should have a profound respect, if not reverence, for her achievements. If we were deprived of the result of modern dentistry alone, we should have a tenfold increase in the number of dyspeptics and rheumatics. Do away

with spectacles and the operation for cataract, let the eyesight of the aged be impaired or destroyed, and again happiness and life are both lessened. From all our therapeutic agents, take away only quinine, mercury and salvarsan, and malaria and syphilis will again take frightful toll of human lives. Forget the work done on hookworm and trypanosomes, and millions of afflicted in our Southern States and in South Africa will lead useless lives until death brings relief. Discard the work of Jenner, and smallpox will again carry away its annual hundreds of thousands. Reject the laborious results of Sternberg, Saranelli, Reed, Carroll, Gorgas and Noguchi, and yellow fever will again mow down its victims so rapidly that the long trenches will be piled deep with nameless dead. Make it impossible to study further the means of preventing and curing consumption, and this deadly Moloch will increase again its toll of thousands of human beings each day. Deprive us of the discoveries of Kitasato and Yersin, and let us remain in ignorance of how the plague is carried and again witness, as did our forefathers, this great tidal wave of death, as it sweeps country after country. Abolish the treatment for tetanus and hydrophobia, and witness again those terrifying scenes that caused whole communities to gather in weeping and prayer. Blot out the work of Behring, and diphtheria will again take our loved ones, by the score, where it now takes but one. Forget the work of Pasteur and Lister, neglect asepsis in surgery, and nine out of ten who go to the operating table will pass on to the grave. Finally, let us reject the discoveries of Wells, Morton and Simpson and surgery will return to the days before anesthetics, when it was the most awful vivisection, when the operating room was filled with heart-rending scenes: the moans of friends, the wails of kindred, the screams and struggles of the tortured patient who, bereft of reason, was bound to the operating table with straps and cords, while a leg or arm was being sawed off.

From the many achievements of medical science, these few have been cited to show that she has done much and to suggest that she can do more. Through sanitation and hygiene and through better medicine and surgery she has wonderfully reduced the death-rates of medieval days and will reduce the present death-rate in the days that are to come.

The people to-day, as never before, appreciate the fact that the greatest wealth is health. The time is not far distant when each state will have installed the machinery, in the way of clinics, laboratories and libraries, for the study of the causation of disease and its prevention; but all the energy and money expended in clinics, libraries and laboratories will be of little avail unless research ideals form the heart and soul of these organizations. The workers—clinicians, investigators, teachers and students—must be inspired by a desire to know truth for truth's sake. There must be a love for knowledge which far transcends its practical application.

It is thus that we owe wireless telegraphy not so much to Marconi as to Maxwell and Hertz. Our mastery of the air is largely due to the studies of Langley, yet all he realized of the practical application of his studies was an occasional bath in the Potomac. John Hunter's work in comparative anatomy evoked the sneers of his professional contemporaries, but to-day we know that comparative anatomy and comparative physiology have led to the solution of many problems because by such studies they were removed from the complexities which frustrate our researches in the higher organisms.

The studies of Pasteur, on spontaneous generation, were undertaken in this spirit of knowledge for its own sake. Let us hear the words of this great

scientist as he speaks before the Medical Congress in London, on August 8, 1881:

> I should be guilty of ingratitude and false modesty if I did not accept the welcome I have received among you as a mark of homage paid to my labors during the past five and twenty years upon the nature of ferments—their life and their nutrition, their preparation in pure state by the introduction of organisms under natural and artificial conditions—labors which have established the principles and the methods of microbiology, if the expression is allowable. Your cordial welcome has revived within me the lively feeling of satisfaction I experienced when your great surgeon, Lister, declared that my publication in 1857, on milk fermentation, had inspired him with his first ideas on his valuable surgical method. You have awakened the pleasure I felt when our eminent physician, Dr. Davaine, declared that his labors on splenic fever had been suggested by my studies on butyric fermentation and the germ which is characteristic of it. Gentlemen, I am happy to be able to thank you by bringing to your notice a new advance in the study of microbiology as applied to the prevention of transmissible diseases—diseases which, for the most part, are fraught with terrible consequences, both for man and domestic animals . . . It is through this inquiry that new and highly important principles have been introduced into science concerning the views on the contagious quality of transmissible diseases.

Ehrlich has well said that our further knowledge concerning transmissible diseases is little more than diligent empiricism based upon these fundamental studies. It might well be added that Pasteur's discoveries have done more to prolong human life than all other discoveries combined.

I have given these few illustrations for the purpose of further emphasizing the great need in our institutions of learning, of not only accentuating practical knowledge but also the creation of a great fund of knowledge whose present returns are solely the satisfaction of knowing.

When the laws of nature are so well understood that the life cycle now given to the few shall be given to the many, will our attitude toward old age have changed? Will man be content with a life cycle of a century? Will not hope, happiness and enchantment give way, as now, to doubt, sadness and anxiety? The answer[2] is found in lives like that of Confucius, who is said to have described himself as a man who, in the eager pursuit of knowledge, forgot his food; who, in the joy of his ideals, forgot his sorrows and did not even perceive that old age was coming on. Here is an example of that philosophy which counts years by life, instead of life by years. Time may measure physical efficiency, but time can not measure ideals, hopes and dreams.

[2] Another answer is that emphasized, I think, by Haldane to the effect the great sorrows and regrets of life come from its impaired realization and its premature ending; that the organism which has completed its natural cycle faces death with equanimity; and that when science shall enable each man to live out in health and vigor his appointed days death in large measure will lose its sting.—E. P. L.

MEANING, METHODS AND MISSION OF MODERN MATHEMATICS

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I

THE modern conception of mathematics has not yet found its way into the text-books. Even lexicographers, who should know the meaning of words, and on whom most of us depend for authoritative definitions of unfamiliar terms, fail to inform us.

Murray's New English Dictionary conceives mathematics in a strict sense to be "the abstract science which investigates deductively the conclusions implicit in the elementary conceptions of spatial and numerical relations." This definition fails on each of three counts: The conceptions of mathematics are seldom elementary; they are not limited to spatial and numerical relations; the investigations do not generally proceed deductively.

The Century Dictionary, having defined mathematics as the science of quantity, speaks of qualitative mathematics as mathematics kept rigorously free from every quantitative idea. How a branch of the science of quantity can be kept free from quantitative considerations is left for the reader to explain to himself.

Both the definitions cited suffer from arrested development.

To say that mathematics is the science of quantity is like saying that geometry is the science of earth-measurement, since it was to the practical enterprise of land-surveying that geometry owes its origin. It is like saying that trigonometry is the science of triangles, since it was the attempt to solve triangles that gave the science its first impetus, or that algebra is the science of equations, inasmuch as the practical need of solving equations gave birth to algebra.

Mathematics, it is true, originated in the contemplation of magnitude and form. And everything in which quantity or form predominates was at one time considered a part or a branch of mathematics. Thus it came about that astronomy, music and optics were at one time considered mathematical studies.

To escape the dilemma of calling grocers and tailors mathematicians, because they also deal with quantity and form, it was found necessary to distinguish between direct and indirect measurement of quantities. Mathematics was now thought of as dealing with quantities at a distance, quantities non-existent, or inaccessible, such as planetary and stellar magnitudes.

This was the view espoused by the famous author of the Positive Philosophy, who boldly announced in his first chapter of his first book, "the object of mathematics is the indirect measurement of magnitudes, and it purposes to determine magnitudes by each other, according to the precise relations which exist between them."

But the ink had scarcely dried on Comte's pen when von Staudt discovered and expounded his "Geometrie der Lage," in which quantitative ideas are completely ignored. Von Staudt's book was published in 1847 and in the same year appeared Boole's "Mathematical Analysis of Logic," the forerunner of his immortal "Laws of Thought," another mathematical work dealing with neither quantity nor form.

Von Staudt's work, perhaps as great and far-reaching in its consequences as Boole's, aroused but little philosophic comment, but Boole's work captivated

the logicians. Russell says it was Boole who *discovered* pure mathematics. Boole was followed by Couterat in a book entitled "The Principles of Mathematics," in which the author tried to show that all mathematics is reducible to logic. Russell proclaimed that "the fact that mathematics is symbolic logic is one of the greatest discoveries of our age and when this fact has been established the remainder of the principles of mathematics consists in the analysis of symbolic logic itself." Keyser in one of his addresses put the thesis in unmistakable terms when he said "Symbolic logic is mathematics, mathematics is symbolic logic, the twain are one."

The view that mathematics is logic and nothing but logic was quite generally accepted by mathematicians as well as by logicians during the last quarter of the last century. W. B. Smith pronounced mathematics the "universal art apodictic," Benjamin Peirce defined it as the "science which draws necessary conclusions," Felix Klein saw in it "fundamentally the science of self-evident things" and Whitehead "the development of all types of formal, necessary, deductive reasoning," and so without end. All agree that in substance the logicians were right.

Inspired by this assumed epoch-making discovery, there now followed in rapid succession the great masterpieces of logistics—Peano's "Formulaire," now in its fifth edition, the wordless book, which by the use of special symbols undertakes to reduce the various branches of mathematics to their irreducible elements, and Whitehead and Russell's "Principia Mathematica" with an aim even more ambitious, that of deducing the whole of mathematics from certain undefined mathematical constants and certain indemonstrable propositions, exactly nine of the one and twenty of the other, no more nor less. The first page of the first volume of Russell's "Principles of Mathematics" contains what is perhaps the most famous definition of mathematics ever advanced, a definition that might preserve its dignity even beside Spencer's famous definition of life. Russell's definition reads:

> Pure mathematics is the class of all propositions of the form "p implies q," where p and q are propositions containing one or more variables, the same in the two propositions, and neither p or q contains any constants except logical constants. And logical constants are all notions definable in terms of the following: Implication, the relation of a term to a class of which it is a member, the notion of *such that*, the notion of relation, and such further notions as may be involved in the general notion of propositions of the above form. In addition to these, Mathematics *uses* a notion which is not a constituent of the propositions which it considers—namely, the notion of truth.

In another place Russell tried to popularize this definition by putting it into the following paradoxical form:

> Pure mathematics consists entirely of such asseverations as that, if such and such a proposition is true of *anything*, then such and such another proposition is true of that thing. It is essential not to discuss whether the first proposition is really true, and not to mention what the anything is of which it is supposed to be true. . . . If our proposition is about *anything* and not about some one or more particular things, then our deductions constitute mathematics. Thus mathematics may be defined as the subject in which we never know what we are talking about, nor whether what we are saying is true.

Despite its wide-spread acceptance, this view of mathematics, set forth with such assurance, had soon to be modified. Why? Because it could not reconcile the two adamantine facts, that logic is barren, while mathematics is the most prolific of mothers. Said Poincaré:

> If all the propositions which mathematicians enunciate can be deduced one from another by the rules of formal logic, why is not mathematics reduced to an immense tautology? The syllogism can teach us nothing essentially new, and if everything is to spring from the principle of identity, everything should be capable of being reduced to it. Shall we then admit that the enunciations of all those theorems which fill so many volumes are nothing but devious ways of saying A is A?

After a most careful analysis of the premises of the logicians, in the second book of his "Science and Method," Poincaré comes to the conclusion that "logistics has to be made over and one is not sure what can be salvaged. It may survive as a branch of mathematics, but it has to abandon its claim to the overlordship of the mathematical world." Far from identifying mathematics with logistics, a closer examination reveals logistics as a water-sprout which has shot up from the parent tree—the giant Sequoia—oldest and mightiest of all the living creatures of the human mind.

What, then, is mathematics? Some think that because mathematics is a living, growing thing, it can not be defined. Says Shaw in his "Philosophy of Mathematics":

> The varied character of its content makes it impossible to reduce all mathematics to either arithmetic, geometry, logistics, calculus of operations, algebra, or transmutation. Nor can we define it more successfully as the study of form, or of invariance, or of functionality, or of theory of equations. It has been the effort of some to define it in terms of its sources, but it is not possible to limit it to the phenomena either of the natural world, the world of universals, or the mental world. Definitions that are based upon methods are no more successful, whether we emphasize its scientific procedure in observations, generalizations, and analogy, or its intuitive insight into the nature of things, or its deductive chains whose invulnerable links support the weight of modern science; nor yet is it wholly the spontaneous product of the imagination of an artist, whose material is not the solid granite of the architect, the flowing marble of the sculptor, the brilliant pigments of the painter, the rippling language of the poet, or the pulsing air of the musician, but is the delicate ether of pure thought. We cannot define it either by its applicability to the world at large, in any realm of validity. In none of these ways may it be defined, for it is all these and more. It may be studied in its varied aspects just as a man may be studied, but no definition based upon any one aspect will be sufficient to include the living creature itself. In short, mathematics is independent of any other branch of human knowledge. It is autonomous, and in itself must be sought its nature, its structure, its laws of being. Not in philosophy, not in science, not in psychology, not in logic, can we discover these things, but only in mathematics.

This view I do not concur in, for I think it may be shown that mathematics is characterized not, indeed, by its applications nor by its method, as has frequently been supposed, but by its content, by the nature of the material with which it works.

Let us then turn to some of the familiar branches of mathematics and see what it is that characterizes the notions that enter them.

Let us begin with arithmetic. Arithmetic deals with numbers, you say, but what is number? The term is used in every branch of knowledge, yet the mathematical concept of number is not knowledge gathered from experience alone. You may say that it is the symbol used to indicate the "how many," the one and only invariant of an aggregate whose members are subjected to all conceivable changes which do not destroy the separateness of the members. This definition is frequently accepted, but number thus defined is not number as the mathematician knows it. If number were an inherent property of physical aggregates and nothing more, then there would have to be a greatest number, all physical aggregates being finite. Then addition would be possible only so long as the sum of the addends does not exceed the greatest number. There could be then no general process of addition or of multiplication or of any other operation with numbers. To make arithmetic possible we not only abstract from experience, we go further and augment experience. And this process of augmentation is really the important thing, it is that which alone makes the science of arithmetic possible. We inject into our concept of number a property which is not the result of experience at all, namely, the property that for every conceivable number there exists one which is greater. Thus we see that number is not a physical property but a creature

of the thinking mind: it embodies the idea of never ending, of what we call the mathematical infinite. The basic concept of arithmetic is more than a mere abstraction. It is a concept suggested, to be sure, by experience, but it transcends experience, it is what we call an ideal construct.

Let us next turn to geometry. The subject-matter of geometry, it is said, consists of points, lines, angles, surfaces, etc. But what is a line? Certainly it is not the mark of ink or graphite that we spread on a sheet of paper to visualize the concept. The mark that represents the line has all the properties of matter—length, breadth, thickness, color, mass, density, etc. The geometrical line partakes of none of these. It can not be seen nor felt nor weighed nor measured. Is it then a mere abstraction? That is the common view but an erroneous one. For we may abstract from a material line all its physical attributes and what remains is not yet a line, but a segment of a line. So much experience suggests, but more is necessary before we have the concept which alone makes geometry possible. It is essential that in general two lines which lie in the same plane should intersect, and that three lines should form a triangle, while obviously two material lines will rarely ever intersect and it is a very remote probability that three random material lines should form a triangle. Abstraction once more is powerless, we again must inject into our concept the idea of never-ending—the mathematical infinite. For every imaginable point on the line we conceive of two others, one on each side of it, so that there is no first point and no last point. The line concept, like the number concept, is an ideal construct—suggested by experience to be sure, but transcending experience—a creature of the thinking mind.

As a third illustration, let us seek the origin of the axiom which constitutes one of the foundation stones of algebra: the axiom which asserts that things which are equal to the same things are equal to each other. In symbols: If $A = C$, and $B = C$, then $A = B$. Is this axiom the result of experience? Let us see.

Consider a band of color, say 100 feet long, which changes continuously from pure white at one end to black at the other. Suppose now that the band is divided into segments each one inch in length, 1,200 segments in all. No human eye is now able to distinguish between the colors of two consecutive segments. Let us denote the colors of successive segments by $A, B, C, \cdots Y, Z$. Then so far as the human eye can judge, $A = B$, $B = C$, $C = D$, $\cdots$ $Y = Z$. Yet we know that $A \neq Z$, for A is white and Z is black. Experience in this case fails to verify the axiom that things which are equal to the same thing are equal to each other.

The example just cited is typical of all other attempts to verify the axiom experimentally. All such attempts are doomed to fail. Physical objects or phenomena can never be proven equal. Experiment can, at most, show approximate equality. For how can we compare physical objects? By means of sensation which is the only avenue of becoming aware of the objects and their differences. Sensations depend upon stimuli, and sensations are indistinguishable if their stimuli differ by sufficiently small amounts. A weight of ten grams and a weight of eleven grams are known to produce identical, that is, indistinguishable, sensations, so do two weights weighing eleven grams and twelve grams, respectively. But the sensations produced by two weights of ten and twelve grams are distinguishable. So far as we can judge by sensations things equal to the same thing are not necessarily equal to each other. In short, the axiom that things which are equal to the same thing are equal to each other can not be established by experience or experimentation. It is in fact a definition

in disguise, a definition of the concept equality, another ideal construct.

Now what has been said of the mathematical concepts of number, line and equality is true of every other mathematical concept, and this is one of the really distinguishing features of mathematics. Take any other mathematical concept which occurs to you—point, plane, circle, angle, sphere, continuity, invariance, infinitesimal, transformation —closely examined each of them is found to be an ideal construct, suggested by experience but not limited to experience, and it is because these ideas transcend experience that they are mathematical.

I have said that the axiom or postulate that things which are equal to the same thing are equal to each other is in reality a definition of equality. A similar statement can be made of any other axiom or postulate. Failure to recognize this truth has led to all kinds of confusion. If there is a difference between definition by postulates and direct definitions, it is this, that as a rule the former applies to a system of things. A system of postulates is an enumeration of the fundamental relations between the members of the system, from which may be derived all other properties of the system, and which, therefore, virtually defines the system.

Each system of postulates then defines the raw material of a field of mathematical thought and constitutes a branch of mathematics. The material thus defined is as truly ideal as if it had been directly defined.

Stuart Mill held that every definition presupposes the existence of the thing defined, existence being understood in the empirical sense. In defining a circle, Mill would say, we affirm that there are round things in nature. But it is obvious that a line, as we have defined it, does not exist in nature, nor does any other ideal construct. A mathematical construct exists if its definition involves no contradiction, a mathematical theorem is true, if it is consistent with the premises. From this point of view it is evident that no mathematical proposition can be established by experiment.

Astonishing as this assertion may seem to you, it is incontrovertible. Consider any mathematical proposition that comes to your mind, let us say the pons asinorum—the square on the hypothenuse of any right triangle is equal to the sum of the squares on the two sides. Suppose, contrary to fact, that it were possible to measure exactly the sides of physical triangles, and suppose that the sides of a million different triangles had been measured and that the theorem had been found true in each of the million cases, there would still remain millions of other cases among which there might be, for all we know, one or more triangles for which the theorem would not be true. If you say that this process would establish the truth of the theorem in the same way that other scientific truths are established and with as much certainty, I can only say mathematical truths differ from scientific truths in just this, scientific truths are never more than probable truths, mathematical truths are never less than absolute truths. We have here another distinguishing mark of mathematics.

The idea is worth pursuing further. Consider the set of mathematical propositions known as Euclidean geometry. They are characterized by the so-called eleventh postulate which asserts in substance that through a point one and only one line can be drawn parallel to a given line. This postulate may be replaced by this other: The sum of the angles of a triangle is equal to two right angles. Furthermore, it is easily shown that if there exists one triangle whose angle sum is two right angles the same is true of every other triangle. Euclid's eleventh postulate, therefore, is equivalent to the assertion: There exists a triangle whose angle sum is two right angles. In this form of the postulate we most clearly

recognize the futility of any attempt to prove it by experiment, for we have seen that no physical magnitude can be measured with absolute precision. We may, therefore, accept or reject the eleventh postulate. If we accept it, or its equivalent, namely, that the angle sum of a triangle is two right angles, we are led to a body of propositions which constitute Euclidean geometry; if we reject it, we must accept one or the other of two alternatives. If the angle sum of a triangle is not equal to two right angles, it must be either greater or less. Either assumption leads to a set of self-consistent propositions, the latter to a set of propositions known as the Lobatchevkian geometry, the former to a set of propositions known as Riemannian geometry. In terms of the parallel postulate a geometry is Euclidean, Lobatchevkian or Riemannian, according as we assume that through a point may be drawn one line, two lines or no line parallel to a given line. Each of these geometries is as true as the other, in the sense that they are equally self-sufficient. If we ask which of these geometries is true in the physical sense, that question has no meaning, for we have seen that geometry does not deal with physical objects, nor with physical properties. As Poincaré puts it in one of his essays, "the question as to which geometry is the true geometry is as meaningless as the question whether the metric system or the English system of measurements is the true system."

This example has been dealt with at some length in order to show that there is no essential difference between direct definitions and definitions by postulates. Postulates are conventions, limitations, if you please, which the mathematician imposes on the creatures of his imagination. These creatures are real only in the sense that they are conceivable; the theorems which he deduces regarding them are true only in the sense that they are consistent. It is this property that enables the mathematician to exercise absolute freedom in the choice of his material and the choice of his postulates. This is what is meant when we say that mathematics is an autonomous science, that the essence of mathematics lies in its freedom.

Now because mathematics deals with ideal constructions, and exercises the utmost freedom in the choice of its material, it has been supposed that this choice is arbitrary or capricious. Indeed, there is a wide-spread suspicion that a great deal of mathematical theory is entirely unrelated to life or to the material world. Some definitions, as Pieri's of mathematics as the hypothetico-deductive science, or Russell's of mathematics as the class of all propositions of the type 'p implies q', do seem to warrant the view that one set of conceivable definitions, one set of consistent postulates is as legitimate a starting point for a mathematical investigation as any other. Such a view, however, reduces the principle of "science for science sake" to an absurdity. An aimless concatenation of random consistencies would be as fruitless as the pastime of constructing anagrams or cross-word puzzles.

The mathematician exercises freedom, but it is freedom tempered by wisdom. From among an infinitude of conceivable ideal constructs, he is guided in his choice by a discernment of what is important, by a delicate discrimination of what is typical, by a penetrative insight and intuitive perception which enable him to single out the essential characteristics of a phenomenon or set of phenomena whose explanation is sought by the inquiring mind. Thus the postulates which form the basis of the various systems of geometry are not arbitrary propositions, but reasonable propositions, as Klein calls them, which have their origin in space intuition. For this reason the theorems of geometry apply more or less accurately to physical space,

they constitute the ideal handling of space relations.

Mathematics, then, is the ideal science, the science par excellence, which furnishes, as it were, the framework, the patterns which underlie the manifold phenomena of the physical world. It is a hyper-world, a super-sensuous world, the most stupendous and sublime of all fictions, yet a fiction which is true to reality, which matches reality at every point. It replaces the obscure images of sense by well-defined counterparts, and the vague and fleeting objects of the perceptual world by ideal constructs, constructs amenable to precise treatment. Mathematics in the main occupies itself with the discovery of ideal relations which are approximately matched, asymptotically approached, we might say, by the phenomenal universe.

II

Let us now turn from the meaning of mathematics to a brief discussion of its methods. The popular view, sanctioned by such definitions of mathematics as most dictionaries give, is that mathematics is the science of deduction par excellence, a view which culminated in the theory that all mathematics is logic. This view does indeed account for the perfect rigor of mathematical conclusions, but it leaves one at a loss to account for the endless variety of its astonishing results. This view, as we have already seen, involves an irreconcilable contradiction. A logical mill grinds only what is put into the hopper—it can change the form but can add nothing to the substance. What, then, is the source of the endless vistas of new relations, new properties, new truths which the mathematicians produce from an apparently inexhaustible store? The contradiction can only be removed by accepting an entirely different view of the methods by which mathematics proceeds in its discovery of truth.

The reason for this mistaken view that mathematics proceeds by deduction is due to the circumstance that the results of mathematical investigations have been traditionally invested in deductive form. It was the method which Euclid chose in compiling his Elements of Geometry. It is the form in which Archimedes made known to the world the fruits of his labor. The great weight of his example established the procedure for others, until it has become the vastly predominating, if not the exclusive form, in which the results of mathematical inquiries are cast before they are published. But every mathematician knows that the method of mathematical exposition is seldom, if ever, the method of mathematical discovery. A finished demonstration rarely ever gives a hint as to how the results were arrived at in the first place. Deduction, it is now held by many, has frequently been deliberately chosen as the most effectual means of hiding discovery, a successful method of effacing all traces of the tortuous paths which preceded the construction of the finished highway. Or if I may change the figure, deduction is, as it were, the finishing process to which the mathematical product is submitted before leaving the factory, the veneering which covers up not only the blemishes and imperfections but also all details of construction.

A misconception once firmly intrenched and supported by eminent authorities, however mistaken, is difficult to dislodge. Was it not Huxley who said that the mathematician is occupied with nothing but deduction and verification since all the inductions he needs were completed ages ago? And again that mathematics "knows nothing of observation, nothing of experiment, nothing of induction, nothing of causation."

Yet I venture to show that deduction, far from being the exclusive method of mathematical investigation, is not even

its predominant method. Mathematical problems are more frequently solved by analysis than by synthesis and inductive reasoning far outweighs deductive reasoning. Actual discovery in mathematics proceeds by cooperative efforts of all the mental powers. Progress in mathematical investigations depends upon comparison and generalization quite as much as does progress in the physical sciences. And as in the physical sciences, so in mathematics, isolation, observation, classification, trial and verification are constantly employed.

In opposition to Huxley's view on a subject which he did not understand, let me quote the views of two mathematicians of the first rank: Sylvester, the father of American mathematics, said:

> Mathematical analysis is constantly invoking the aid of new principles, new ideas, new methods, not capable of being defined by any form of words, but springing direct from the inherent powers and activities of the human mind, and from continually renewed introspection of that inner world of thought of which the phenomena are as varied and require as close attention to discern as those of the outer physical world, . . . it is unceasingly calling forth the faculties of observation and comparison, one of its principal weapons is induction, it has frequent recourse to experimental trial and verification, and it affords a boundless scope for the exercise of the highest efforts of the imagination and invention.

The same view was voiced by Hobson in his presidential address before the British Association for the Advancement of Science in the words, "the actual evolution of mathematical theories proceeds by a process of induction employed in building up the physical sciences; observation, comparison, classification, trial and generalization are essential in both cases." To the charge that mathematics knows nothing of causation, Hobson said:

> The opinion appears to be gaining ground that the very general conception of functionality, born on mathematical ground, is destined to supersede the narrower notion of causation, traditional in connection with the natural sciences. As an abstract formulation of the idea of determination in its most general sense, the notion of functionality includes and transcends the more special notion of causation as a one-sided determination of future phenomena by means of present conditions; it can be used to express the fact of the subsumption under a general law of past, present and future alike, in a sequence of phenomena. From this point of view the remark of Huxley that mathematics "knows nothing of causation" could only be taken to express the whole truth, if by the term "causation" is understood "efficient causation." The latter notion has, however, in recent times been to an increasing extent regarded as just as irrelevant in the natural sciences as it is in mathematics; the idea of thorough-going determinancy, in accordance with formal law, being thought to be alone significant in either domain.

But why rely on authority where the facts are accessible to all? It is obviously true that many geometrical truths must have been the result of observation long before they yielded to demonstration. If proof were needed we might cite the fact that every child knows a considerable number of geometrical facts long before he takes up the study of demonstrative geometry. Such facts as that parallel lines are everywhere equally distant; that one side of a triangle is less than the sum of the other two; the propositions regarding the congruence of triangles; the essential properties of isosceles and equilateral triangles, and many others are matters of common observation. Who can doubt that such relations as those between the squares of the three sides of a right triangle, of the angles inscribed in a semicircle and multitudes of others, were observed to be true long before they were demonstrated mathematically? Surely, all applied mathematics proceed by observation, namely, the observation of order and regularity or periodicity and symmetry which attract attention and invite investigation. The observation that circles, ellipses, parabolas and hyperbolas can all be cut from the same cone incited the early Greek mathematicians to the pursuit of the marvelous relationships and proper-

ties of the conic sections. The path of a fixed point on a rolling wheel, actually seen or imagined, was the occasion which led to the elaborate theory of cycloids and trochoids. Certain relations observed while constructing his planetarium led Huyghens to conceive and develop the theory of continued fractions. If you will pardon a personal allusion, I will add that it was observation of the wonderful symmetry and beauty of the curves described by a toy called the wondergraph that suggested to me the conception of cyclic-harmonic curves, the theory of which absorbed my attention for several years.

Let us next consider generalization. Instead of being foreign to mathematics I consider it one of its most fruitful methods. Looking over a list of my own contributions in mathematics, I find that nearly one fourth of them originated in the attempt to generalize known results. My first doctor's thesis deals with an extension and subsequent generalization of the differentiation process. Differentiation is based on the assumption that all quantitative changes are due, or may be conceived of as being due, to accretions, that is, the increments of the variables under consideration are taken as additive. The limit of the ratio of corresponding additive increments of the dependent and independent variable is called the derivative, and this is the fundamental concept of the differential calculus. Now it occurred to me that quantitative changes could as well be thought of as due to expansion, and corresponding changes compared by means of their logarithmic ratios. The limits of such ratios I called quotiential coefficients, and I was able to show that it is possible to develop a complete calculus, whose fundamental concept is the quotiential coefficient, and that this calculus is not only self-consistent, but could be employed for the interpretation of natural phenomena quite as well as the differential calculus.

Later I was able to show that the quotiential calculus and the differential calculus are but two links in an endless chain of calculi. A slight modification in the so-called involution process leads to an infinite sequence of processes of which any consecutive three are related in precisely the same manner as are addition, multiplication and involution. Each consecutive three of this sequence of processes may now be employed to define a limiting process completely analogous to differentiation. This process I have called ratientiation, the corresponding calculus, the calculus of ratients.

Again the largest of my later papers which deals with the sums of products on n consecutive integers is a generalization of the results of a score of papers dealing with the sums of products of the first n integers. Incidentally during the course of this investigation I was led to a generalization of Wilson's theorem, one of the most fundamental theorems in the theory of numbers, and which had already been generalized in various directions. Each generalization, of course, extends the domain to which the theorem applies and, therefore, increases its usefulness.

I have chosen these two examples of the use of generalization in mathematical research from my own work because they happen to be examples that are easily understood. But it is not necessary to stop with examples. There are whole branches of mathematics which consist in a large measure of generalizations of known results. Take spherical trigonometry. All the theorems relating to spherical triangles are, in a sense, generalizations of the theorems relating to plane triangles. By making the curvature of the sphere equal to zero, any formula of spherical trigonometry goes over into a corresponding formula for plane trigonometry. Many of the theorems of analytical geometry of three dimensions are generalizations of corre-

sponding theorems in two dimensions. The theory of functions of a real variable deals with generalizations of concepts and theorems of elementary calculus. The theory of functions of a complex variable consists largely in the generalizations of theorems pertaining to real variables. In fact it would be difficult to mention a branch of mathematics which is not the outgrowth of the attempt to generalize known results.

Generalization, then, must be put down as one of the dominant methods employed in mathematical research. In fact, this might be anticipated from the outset. The mathematical concepts, as we have seen, are the combined results of abstraction and generalization. Generalization is so typical of mathematics that some one has said, "Whatever the mathematician touches he changes—you hand him one thing and he returns something different." It is this that makes it so difficult to follow a mathematical discourse and that frequently makes it appear as if the mathematician talks nonsense. It is because the things he talks about are no longer the things which you know by the same name, but generalizations of them. The things you call number, points, lines, angles, sum, multiplication, power, root, have grown into something quite different under his hands. He has extended, transformed, generalized each of these things and by so doing has created a new universe with properties and phenomena undreamed of before. What are complex numbers, quaternions, transcendental numbers, ideal numbers, transfinite numbers, matrices, vector systems, hyperspaces and the elaborate theories based upon them but the results of generalization, applying known results and laws to ever larger and more diversified categories of things?

One form of generalization is known by the same induction. If Huxley said that mathematics knows nothing of induction, Poincaré, one of the greatest mathematicians of all time, considered induction as the very essence of mathematics, the one principle without which mathematics as a science could not exist.

The veriest tyro in mathematics knows that induction is used incessantly as a method of arriving at new results. Every elementary text-book of mathematics abounds in theorems which the student is led to discover by induction before they are demonstrated. Illustrations are the theorems relating to the divisibility of the sum of two odd powers by the sum of the numbers; of the difference of two even powers by the sum and the difference, the binomial theorem for positive exponents, the theorems for the summation of series, and countless others. And induction as used as an aid in discovery in mathematics is of precisely the same type as that used by the naturalist or physicist. It consists in the anticipation of a general law or relation from a number of specific instances. The fact that mathematicians do not accept the results suggested by induction as finally established until arrived at by demonstration does not destroy the utility of the method as an aid in mathematical research.

Observation, generalization, induction are as essential and of as common use in mathematics as in deduction proper. Nor is experimentation entirely foreign to mathematical research. It is said that Archimedes determined centers of mass geometrical figures by actually balancing on points and knife-edges material solids representing such figures. Eratosthenes became famous through his experimental method of constructing a table of prime numbers. In geometry models and drawings are used constantly to aid the imagination in its grasp of relations, to anticipate new properties, as well as to verify theoretical results. As great a modern mathematician as Felix Klein charged metallic plates electrically in order to prove the existence of functions

possessing certain singularities. The distribution of the current on the plates, he reasoned, would correspond to functions of the type sought for.

While the use of experiment as a method of mathematics is, no doubt, limited, its use in verification is universal. He knows little of the methods employed by mathematicians and certainly has never seen a mathematician at work, who imagines that theorems spring forth full-fledged from the mathematician's brain. The most recondite theorems in number theory, the most abstract of all mathematical theories, are submitted to numerical verification whenever possible. Sometimes weeks are spent in the numerical verification of a theorem that can be stated in a single line. Such verifications are seldom published and frequently not even mentioned, yet it is safe to say that in the aggregate much more time is spent by the average mathematical investigator in trial and verification than is spent in the derivation of his theorems. Eminent mathematicians are on record as having resorted to thousands of trials to verify single elementary conclusions in probabilities.

I think we are now in a position to see why mathematics progresses by leaps and bounds even after centuries of evolutionary development. It is because mathematicians avail themselves of the methods that alone are fertile. "There was more imagination," said Voltaire, "in the head of Archimedes than in that of Homer." "The moving power of mathematical invention," said the great DeMorgan, "is not reasoning but imagination." In fact all the powers of the mind are marshalled to united effort, all the methods known to science are drafted into active service, for the advancement of mathematical knowledge, for the discovery of mathematical truths. It is only after new relations have been surmised, new theorems anticipated and new problems formulated that ratiocination can do its work, that strictly logical methods of thought are applied to complete the structure by giving it that permanent, imperishable form which characterizes the mathematician's work.

III

I now come to the third and final part of my subject—the mission of the modern mathematics. The term mission suggests that I am not thinking of the manifold material advantages which have accrued to mankind through the use of mathematics in the shop, the factory and the counting house; through its application to surveying, to navigation, to the building of aqueducts, canals, railroads, bridges and highways; or to the aid it has rendered the architect and the master builder; or the share it has had in the achievements of all forms of modern engineering, whether naval, civil, mechanical, hydraulical, electrical or aeronautical, which through their conquest of the physical forces of nature have immeasurably improved the living conditions of mankind. Nor am I thinking of the indispensable aid that mathematics has rendered to the other sciences, to physics, to astronomy, to chemistry, to statistical science and to the science of risks, many of whose problems are not even intelligible without a considerable knowledge of modern mathematics. Nor do I wish to dwell on the central rôle which modern mathematics has played in every serious attempt of modern philosophy to find a "cosmos in the seeming chaos of the physical universe." All these topics are worthy of separate considerations, but the present hour is all too short for that purpose.

In speaking of the mission of mathematics I am thinking of mathematics as a spiritual enterprise, which like religion and art ministers to a spiritual need. I want to dwell briefly on the share which mathematics has in those great human interests, those spiritual enterprises, to which we owe such permanent values, as

by universal consent, constitute the most cherished possessions of our race.

That mathematics deserves human regard on the same grounds as poetry, music or plastic art has been recognized from time immemorial. The Pythagoreans conceived of mathematics as the foundation and essence of all art. To them all order and harmony, all law and beauty were but as many different manifestations of number relations. This idea of the close relationship between mathematics and art became a commonplace among the Greeks. It was accepted by the great Aristotle, who, in his Metaphysics, takes to task those who deny that mathematics has anything to do with what is beautiful. "Of what is beautiful," he says, "the most important species are order and symmetry, and this the mathematical sciences make manifest in a most eminent degree." It was, therefore, probably no accident which attracted the great masters in art, notably Leonardo da Vinci, Raphael, Michel Angelo and Alfred Dürer, to the mathematical sciences; or a mere coincidence that the golden epochs in mathematics have always been nearly synchronous with the golden ages of art and literature.

Am I dealing with outworn creeds, with conjectures and doubtful generalities? Let me cite a few witnesses from among a multitude, who can speak with knowledge; for just as it takes a musician to judge fairly the performances of a Wagner or a Chopin, so no one can give a truer appraisal of the esthetic pleasures to be derived from mathematics than its devotees. "Mathematics, rightly viewed," says Russell, "possesses not only truth, but supreme beauty—a beauty cold and austere, like that of sculpture, without appeal to any part of our weaker nature, without the gorgeous trappings of painting or music, yet sublimely pure, and capable of a stern perfection such as only the greatest art can show. The true spirit of delight, the exaltation, the sense of being more than man, which is the touchstone of the highest excellence, is to be found in mathematics as surely as in poetry." Here we have a partial explanation of the community of delight of which Wordsworth must have been keenly conscious when he mused

> "On poetry and geometric truth,
> And their high privilege of lasting life,"

an idea further amplified by the philosopher-mathematician, Thomas Hill, in one of his essays when he says:

> Mathesis and Poetry are utterances of the same power of imagination, only the one is addressed to the head, the other, to the heart. Poesy is a creation, a making, a fiction; and the Mathematics have been called, by an admirer of them, the sublimest and the most stupendous of fictions. It is true they are not only μάθησις, learning, but ποίησις, a creation.

"Who that has studied the works of such men as Euler, Lagrange, Cauchy, Riemann, Sophus Lie and Weierstrass," asks Hobson, "can doubt that a great mathematician is a great artist?"

> However far the calculating reason of the mathematician may seem separated from the bold flight of the artist's phantasy [answers Lampe] it must be remembered that these expressions are but momentary images snatched arbitrarily from among the activities of both. In the projection of new theories the mathematician needs as bold and creative a phantasy as the productive artist, and in the execution of the details of a composition the artist must calculate dispassionately the means which are necessary for the successful consummation of the parts. Common to both is the creation, the generation, of forms out of mind.

Sylvester, the founder of American higher mathematics, himself a man of a highly developed artistic temperament, was ever conscious of the essential unity of mathematics and the fine arts.

> The world of ideas which mathematics discloses or illuminates, the contemplation of divine beauty and order which it induces, the harmonious connection of all its parts, the infinite hierarchy and absolute evidence of the

truths with which it is concerned [he exclaims] these, and such like, are the surest grounds of the title of mathematics to human regard.

And in another place he asks,

May not music be described as the mathematic of sense, mathematic as music of the reason? the soul of each the same! Thus the musician *feels* mathematic, the mathematician *thinks* music—music the dream, mathematics the working life—each to receive its consummation from the other when the human intelligence, elevated to its perfect type, shall shine forth glorified in some future Mozart-Dirichlet or Beethoven-Gauss—a union already foreshadowed in the genius and labors of a Helmholtz!

Expressions like the foregoing could be multiplied almost indefinitely, but one other must suffice. It is Boltzmann's answer to the query, Can anything be beautiful where there is not the slightest attempt at external embellishment? Boltzmann's answer is:

It is this very simplicity, the indispensableness of each word, each letter, each little dash, that among all artists raises the mathematician nearest to the World-creator; it establishes a sublimity which is equalled in no other art,—something like it exists at most in symphonic music. . . . How expressive, how nicely characterizing withal is mathematics! As the musician recognizes Mozart, Beethoven, Schubert in the first chords, so the mathematician would distinguish his Cauchy, Gauss, Jacobi, Helmholtz in a few pages. Extreme external elegance, sometimes a somewhat weak skeleton of conclusions, characterizes the French; the English, above all Maxwell, are distinguished by the greatest dramatic bulk. Who does not know Maxwell's dynamic theory of gases? At first there is the majestic development of the vibrations of velocities, then enter from one side the equations of condition and from the other the equations of central motions—higher and higher surges the chaos of formulas—suddenly four words burst forth "Put $n=5$." The evil demon V disappears like the sudden ceasing of the basso parts in music, which hitherto wildly permeated the piece; what before seemed beyond control is now ordered as by magic. There is no time to state why this or that substitution was made, he who can not feel the reason may as well lay the book aside; Maxwell is no program-musician who explains the notes of his composition. Forthwith the formulas yield obediently result after result, until the temperature-equilibrium of a heavy gas is reached as a surprising final climax and the curtain drops.

Now if it be granted that mathematics has a place among the fine arts, it must have a share in the mission of all art, which I take to be the ministration to the esthetic needs of our race through the creation and revelation of beauty of whatever form. There is, however, still another domain in which mathematics is the chief, if not the sole, ministrant. I refer to the domain of pure intellection, the empire of rationality, the world of concatenated ideas, the only universe in which truth has a meaning.

For what is truth? I need not tell this company of the dismal failure of the search for truth in the world of phenomena. That truth can not be found in the world of sense and matter has been the universal verdict of philosophy throughout the centuries. We are not sure of the facts of nature, much less of its laws, on the contrary we are quite sure that things are not what they seem, and that the laws of nature are but man's attempts to reduce to a semblance of order what would otherwise be but "a big, booming, buzzing confusion," as James once called it.

Yet we are all conscious, too painfully conscious, of a craving for truth, for certainty, for permanence, for something that is stable and enduring. "The cry of the dying Goethe, 'More light, more light,' " says Dodgson, author of "Alice in Wonderland," "is the cry that, throughout all the ages, is going up from perplexed humanity, and science has little else to offer that will really meet the demands of its votaries, than the conclusions of pure mathematics." Mathematics has gradually evolved an ideal world, an ordered cosmos, closely matching though transcending the world of reality, a world amenable alone to the laws of reason, a cosmos in which order and consistency reign supreme. As

Wordsworth has it, "in verity, an independent world, created out of pure intelligence." In this world reason has built itself a home, a dwelling place, whither it can withdraw from the "dreary exile of the natural world." For are not mathematical truths eternal truths? Before the laying of the foundations of the world, and after the heavens shall have been rolled up like a scroll, the endless galaxies of mathematical theorems will shine forth as unchangeably true, as dazzlingly beautiful, as majestically pure and austere as on the days of their births. In this world of ideals, mathematics is symbolized by the Hercules of mythology who liberated the tortured Prometheus, shackled and chained to the rocks.

Clifford in one of his essays speaks of geometry as having been throughout the centuries "the encouragement and guide of that scientific thought which is one thing with the progress of man from a worse to a better state"—the encouragement through its revelation of a body of truth that can be absolutely relied upon, the guide, because it furnishes an ideal of perfection which has been the aim of every other science to approximate. The truth of this view is manifest on every hand. The chemicization of biology, the physicization of chemistry, the mechanization of physics and the mathematicization of mechanics are the successive steps in the gradual approximation of that rationalization of the world of phenomena to which mathematics has pointed the way.

Mathematics thus offers a partial response, and, I believe, the only conceivable response, to one of the three great aspirations of the human soul—the aspirations for the good, the beautiful and the true. And as religion has for its chief domain the search for the good and for its mission to minister to the moral needs of man, as art in its quest for the beautiful ministers to the esthetic life, so mathematics in revealing the meaning of truth has ministered and will ever minister to the intellectual life of men.

The view which I have thus inadequately set forth, though it runs counter to the familiar uses that men see in mathematics, is not new. I think it is foreshadowed in the fine phrase attributed to the Pythagoreans that mathematics is "the purifier of the reasonable soul." What else is the meaning of Plato's "God geometrizes continually"? Goethe must have had the same idea in mind when he pronounced mathematics the "fountain of all thought," and Novalis etherealized it when he called mathematics "the life supreme" and mathematicians "divine messengers." Schellbach said "Who knows not mathematics . . . dies without knowing truth."

In conclusion and for the purpose of reinforcing the view of the chief mission of mathematics which I have attempted to set forth I will quote a paragraph from Keyser's "Universe and Beyond."

> The domain of mathematics is the sole domain of certainty. There and there alone prevail the standards by which every hypothesis respecting the external universe and all observations and all experiment must finally be judged. It is the realm to which all speculation and all thought must repair for chastening and sanitation—the court of last resort, I say it reverently, for all intellection whatsoever, whether of demon or man or deity.

THE "NITROGEN CYCLE" IN EDUCATION

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ONE of our commonest figures of speech makes oxygen the "breath of life." Comparable figures might identify other elements as equally indispensable to existence. Nitrogen in the tissues of the body is as necessary to life as is oxygen in the lungs. The influence of the latter is immediate and direct, however; of the former, indirect and relatively remote. Hence, the importance of the flame over the frame and the fuel has been a matter of common misunderstanding.

Always, of course, there has been a felt need for strengthening and energizing foods, instinctive to all animal existence, including man. Nitrogenous foods have always been sought, first under the native animal urge for survival, and later upon the empirical principle of observed results—for primitive societies are nothing if not pragmatic. But only in relatively modern time has scientific study and description rationalized the universal continuous demand for both oxygen and nitrogen in physical functioning.

It is axiomatic that knowledge of the indirect and remote, like wisdom, lingers. So that, although nitrogen was discovered as an atmospheric element a few years prior to the isolation of oxygen (both coming within the half-decade between 1770–75), the discovery of their true relationship to life was naturally reversed in time. Command and effect of oxygen being direct and immediate, its importance was patent. Not so with nitrogen, however. While, on the average, slightly more than three fourths of the volume of the air we breathe is nitrogen (as compared with but one fifth of oxygen), no direct or immediate interaction between this dominant gas and the body is observable—for the simple reason that it does not exist in any major functioning. The body, which can not subsist without nitrogen, is always immersed in that indispensable gas, breathes and bathes in it continuously; yet is impotent directly to make use of the precious element. For nitrogen is an "inert" gas, as directly unable to take its indispensable place in physical form or functioning as the body is helpless directly to utilize it. Hence, general knowledge of its circuitous ways into the body's multiplicity of cells has been relatively tardy.

Understanding of this devious path of "free" nitrogen from the atmosphere to usable compounds in the body tissues has taken the scientist afield with the humble husbandman. As far back as agriculture existed, undoubtedly, tillers of the soil knew that certain plants (now known as "legumes") were foods of remarkable potency. That was obvious, and simple. But they observed, also, a fact of much mystery, *viz.*, that these same plants instead of exhausting the soil actually enriched the ground from which they drew their substance. Here was one of various matters which smacked of magic; yet a fact established empirically, hence religiously utilized. So it came about that in the times when Asiatic fig growers were mystically hanging cuttings of branches from certain trees among the branches of other trees in order to insure a yield, Roman farmers, and doubtlessly grain husband-

men throughout the earth, were practising the magic of seeding their poorer soils to certain plants (leguminous) in order to enrich them while at the same time deriving from them valuable crops —albeit the Roman custom lacked in sedulousness in later times, if we are to accept the explanation advanced by Lucretius for the fall of the Empire. It remained for modern science to resolve these and many similar riddles of nature. For science, which develops formulae to support or destroy empirical conclusions, has written a simple explanation of the seeming magic of the legumes as one stage or factor in the "Nitrogen Cycle."

The leguminous plants, chiefly clovers, supplemented by peas, beans, etc., in minor rôles, are hosts to bacteria which possess the power denied to man, of transforming or fixating free nitrogen from the air into usable soil compounds available for plants, thence for animal utilizations fundamental to existence. Thus plant life, of specific varieties, constitutes a necessary link between the animal body and its indispensable nitrogen element. Animal life (upon major scale) possesses no such power. True, human intelligence has discovered certain limited sources of nitrogen compounds, and human ingenuity has devised chemical-mechanical means for manufacturing (fixating) usable nitrogen from the air; but neither our Chiles nor our Muscle Shoals may ever meet plant and animal needs for this basic life element without the major service of the legumes.

But the nitrogen cycle in soil fertilization and in maintenance of all animal life is now generally understood. Detailed exposition of the phenomenon is not necessary; hence, the foregoing brief statement of its significance is sufficient to serve the present purpose—which is to point out a parallel in the field of education, and one not so generally understood or appreciated. For the educational field, like the agricultural, must have its "legumes" through which to establish a "nitrogen cycle" indispensable to the spiritual life. Spiritually, man lives within an atmosphere of inert element, indispensable to the good life, but "free," impossible of direct utilization. Spiritual principles or precepts, ideals—the multitude of virtuous abstractions—these constitute the free nitrogen, the inert element of our educational atmosphere. Without them, "being" atrophies, is impotent for growth of good; character becomes a sterile soil productive of nothing better than good intentions.

Just as in the case of free nitrogen in the physical world, one may bathe in and breathe idealistic abstractions and still be barren of positive virtue. For the good life is neither understanding nor feeling, important as these are, but *doing*, the sum total of customary behavior—habit. It follows that right principles affect life only as they find fixation in the soil of constructive human experience. To become effective they must be lived, cumulated in the nodules of desirable neural patterns. Here they constitute a soil enrichment from which spring bountiful harvests of personal-social behavior.

In discovering and consciously employing this "nitrogen cycle" in development of social intelligence, scientific education has been much less progressive than has scientific agriculture. The psychologist has been slow to follow the path marked out by the soil chemist. For, while agriculturists have for centuries recognized their dependence upon the legumes of the nitrogen cycle in maintaining soil fertility, as the indispensable basis of all plant productivity, educationists have gone on fatuously faithful in the expectation that virtue might be absorbed as emotionality if not directly assimilated as understanding.

Hence, social intelligence has been sought as a response to emotional harangue and platitudinous moralizing. And during this time America has been strengthening her hold upon the unenviable reputation of being the least law-abiding country upon the face of the earth! All that we have achieved of individual and national character has been a by-product of pragmatically controlled living rather than a result of abstract vaporizing through which, chiefly, it has been sought. Only recently and then reluctantly are educators relinquishing the hope of inculcating virtue as knowledge or feeling. Only the accumulated teachings of "habit psychology" are checking the earlier waste of breath in academic incantation—are bringing the conviction that morality, civiculture, ethics, religion (whether the religion of emotionality and fear or the religion of rationality towards which we are trending), that, in fact, no single personal-social virtue may become effective unless fixated in the soil of customary behavior. Finally, however, the educator has discovered that just as it is impossible for the body to abstract directly from the air its necessary store of nitrogen, so is it impossible for the non-material being to draw directly from the atmosphere of academic abstractions the store of social intelligence indispensable to the good life. In the former case, man has learned to rely upon nitrogenous foods made possible by nitrogen fixating plants; in the latter case, he is learning to look to habituation made possible by types of education effective in fixating knowledge and feeling into the fertile loam of behavior.

Having finally found the scientific formula for development of the social intelligence, the alert educator has been quick to recognize the media necessary to its application; has identified the "legumes" of the educational field as the so-called "practical phases" of learning. Evidence of this is preponderant in the multiplying of "activity" curricula, the tendency, indeed, to "practicalize" all education by motivating it as natural outgrowths of native tendencies to investigate, to manipulate, to construct; by activating it as repeated response to life-like situations—by fixating the abstract facts of human aspirations into the living truths of human achievements through pleasurable participation in controlled social situations. To-day only a comparatively small and dwindling band of die-hards are clinging blindly to an outgrown philosophy of culture and to a worn-out psychology of disciplinary magic, traditionally ascribed to ancient times and civilizations long dead, as content and method best suited to assure a social intelligence compatible with modern industrial America. An equestrian coat of mail for Mr. Coolidge's mechanical hobby-horse! Within a few years these atavistic advocates will be as rare as are now those who forego strengthening, energizing foods for a more direct extraction of their necessary nitrogen from the atmosphere. The "end of the Middle Ages," foretold by Durant in commenting upon the passing of Santayana, is at hand; "hereafter it is America and not Europe that will write America's philosophies"—including her psychology of learning. Already the Americanization of William James and John Dewey has brought our educational philosophy, both as to end and means, "down from the clouds to deal with the affairs of men." Natural (unbossed) activity, motivated participation in socially desirable "affairs of men" is rapidly becoming the recognized end and way of all modern education, from kindergarten to college.

What the agricultural legumes—clovers, peas, beans, etc.—are in the

nitrogen cycle of the physical life, so are the educational legumes—the industrial, commercial, household and other practical arts—to the growth and maintenance of the spiritual life. As content, they supply to childhood and youth a bountiful harvest of basic social-economic understandings and fundamental skills—as essential to social adaptation as the mother tongue. Among these practical arts, the industrial are dominant, for the simple reason that America is dominantly industrial. The first requisite towards effective citizenship is all-round industrial intelligence—elementary understandings, appreciations, and control of the simplest mechanisms which, in their fullest development, are characteristic of that intensely industrial democracy which is America. These fundamentals constitute the content of the practical arts—immediate "food values" of these "legumes."

But as method they are equally important. For, like the legumes, while they supply directly a valuable harvest, also they enrich the soil in which they grow, with their wealth of actual or life-like situations, in interaction with which children and youth crystallize desirable habits of living. Thus they motivate, they activate, they integrate learning through social participation—in short, they fixate the free element of virtuous abstractions into personal-social habituations which in sum total constitute the worthy spiritual life.

SCIENTIFIC FANTASIES

By Professor D. W. HERING
NEW YORK UNIVERSITY

Is science out of place in the realm of fancy or fancy in the realm of science? It is the poet's privilege to soar upon clouds of idealism; is it not the métier of the scientist to attend strictly to material affairs and serve the arts of commerce and industry? That idea is widespread: let the shoemaker stick to his last—although it is on record that a shoemaker, one William Carey, managed to make a deep spiritual impression upon the world. The scientist is supposed to be a prosaic sort of individual who devotes himself so completely to facts that he must beware of displaying a lively imagination. Not that he would amount to anything if he were devoid of imagination—he is no true scientist if he does not possess this dangerous treasure—but it should be kept in the background. Enthusiasm that would excite admiration if directed to sports or business would rather disqualify a professional scientist hoping for the approval and support of the man of affairs. There may be occasions in which he can use his enthusiasm to inspire others, but, for the most part, he would better keep this (like other stimulants) for home consumption. He should not let it become conspicuous. In popular estimation, if he is suspected of such a failing, he is distrusted. The busy world is practical and the practical man has little sympathy with anything that smacks of the visionary. Impatient to discover the "practical" value of an idea, he asks "What has this work-a-day world to do with fantasies?" Well, it has more to do with them (or they with it) than is commonly supposed; for fantasies, even scientific ones, are not all harebrained. What with the achievements of science popularized and exploited in "Creative" this, "Marvels of" that, the other "In Industry," and the "Boy's Book" of them all, entertainingly written and richly illustrated, the impression is produced that the only merit and almost the only interest in science lies in its application to industrial and commercial pursuits. If the writers of these fascinating dramas of discovery and invention give a glamor of romance to the careers of the actors in them, it is usually a romance that reaches its climax in immense industrial works or colossal fortunes attained after early struggles and disappointments. Therein, apparently, lies the only excuse for science and scientists, and the stories are of a nature to emphasize this misconception of science, whether they are meant to do so or not. They are buttressed by columns of figures—correct, perhaps, but leaning like Pisa's Tower—and the pen pictures are drawn in grotesque perspective. The reaction to this of a person who is not disposed to deify trade or manufacturing is to look upon science as at bottom prosaic if not actually sordid, and all that is not materialistic in him is repelled rather than attracted by it; and, moreover, it leads him to put an unfortunate construction on that magic word "success." We hear of art for art's sake, and we are taught to scorn the spirit of the miser who accumulates money for money's sake, but we do not hear enough of science for the sake of science. The traits that inspired Galileo, Newton, Faraday, Bunsen, Kelvin, Pasteur and many other heroes who refused to capitalize their genius in cash or securities or to surrender to the promise of great wealth their devotion to science for its

own sake, are obscured by the glare of commercial aggrandizement. To the credit of modern industry be it said, however, that its captains to-day have gone far in the recognition of the material advantage to be derived from pure science and now foster it to an extent and in ways which they would have disdained a half century ago. Perhaps we shall learn that scientific endeavors may be fruitful and may teach wholesome lessons without regard to so-called "utilities." Initial success in a small way does lead to commercial development and this, in turn, supplies the means and the incentive to further scientific research, but it is the scientific enthusiast, not the profit seeker, who sets the ball rolling and overcomes the early difficulties and disappointments. Capital is too sensitive and too cautious to venture upon an enterprise before it sees a good prospect of financial return.

Since fantasies may be wildly speculative and in no case need be conclusive, the scribe who writes of them may take comfort from the thought that he can not be held responsible for the truth or the want of it which they may display; nor is he under any obligation either to maintain or to refute them. In his most irresponsible mood, however, it is a satisfaction to him to perceive how intimately many a fantasy, with its contradictions and extravagances, is associated with sober human experience—a satisfaction that will stay with him so long as he remembers that the uncertain ideas and unstable conditions may be only fantasies. We have been reminded repeatedly that the profoundest reflections of the natural philosopher—ideas that have led to the ocean cable, the electric dynamo or the airplane—have never lacked a romantic element, and our pleasure in the thought rises as we realize that this is as true to-day as it ever was. No fantasies in science? That is an unfortunate misapprehension; scientists themselves protest against it but with not much success. Aladdin and his lamp, the magic carpet, Sindbad and other stories from the Arabian Nights; imaginative strivings of medieval gropers or dreamers; searchings of the heavens by Galileo or Kepler; speculations of spiritualists; were not more distinctly fantasies than the present-day probings and daring hypotheses that are opening the inner recesses of Dame Nature's sanctum; and these must be always of the nature of fantasies until prolonged experience brings them out of the clouds and places them upon a solid footing. Sometimes, it is true, they prove to be mists that are soon dispersed, but even these are interesting while they last. When the morning newspaper brings us the announcement of some new achievement or discovery, as morning newspapers have fallen into the habit of doing, our wonder and admiration are concentrated upon the thing itself; not until long afterwards, perhaps when claims of priority are under discussion or litigation arises over "rights," do we appreciate the work of imagination that culminated in a great realism—mental pictures, cogitations, plans, a system of arteries and veins that distributed the life blood upon which the scheme lived and grew and matured. Assuredly, not all grow up; many never come to light, and among the waifs and strays of mental progeny are lame and misshapen figures, the outcome of ill-conceived or misdirected fantasies. Induction is not sufficient. Groping after clues, speculation as to how to account for new phenomena, has compelled scientists boldly and violently to burst the trammels of what had seemed to be laws that proved inadequate to new discoveries, and each discovery but adds new perplexities. For example, the line spectra of elements, in their simple form long a powerful means of analysis along narrow separate paths, have become a wilderness; energy in *quanta* instead of continuous flow brings out new relations

(or new explanations) of matter, energy, electricity, light—in short, the constitution of the universe. It was a poet of the seventeenth century who used the startling figure of "the wrecks of matter and the crush of worlds," it is the physicist and chemist of the twentieth who pictures to us the shattering of the atom and the construction of a world. It is only ignorance that fails to see in the scientist the richest faculty of imagination, and it is a mistake to think that he deals only with assured facts; he dreams dreams and sees visions, not at all to his discredit if he is not thrown off his balance by them. Although the truth is his goal ultimately, his fancies make the path to the goal sometimes flowery even if the facts are thorny. A difference—perhaps the most significant one—is that whereas the fantasies of a story-teller are likely to be woven when the author is in a dreamy state, with eyes closed, those of science are the product of a weaver whose eyes are open and who is very wide-awake.

Has art staged anything more dramatic than the following sequence of events? The first conversation by Dr. Alexander Graham Bell over the telephone was on March 10, 1876, from his workroom upstairs to the cellar; electric waves from a spark discharge, foreshadowed in the work of Faraday and forecast by Maxwell, were first detected by Dr. Heinrich Hertz in 1887. These were strictly laboratory performances; both events were like newborn infants and required careful, skilful nursing and, like the often cited baby, were of doubtful use. On March 7 ,1926, fifty years lacking just three days after Dr. Bell's success and not quite forty years after that of Professor Hertz, conversation was carried on between New York and London for several hours, broadcast in electric waves and heard by telephone! Professor Hertz had died thirty-two years before this, and Dr. Bell as many months, but the work of these pioneers had been pushed by others no less devoted to it. Scientists were not so dull as to be unaware of the commercial importance of their discoveries, but the great possibilities of financial gain contributed very little to the thrill that came, on these several occasions, to the men whose genius brought about this astounding dénouement. Fantasies? We are not to suppose that final results (if the results are final) are exactly like the image the worker had in mind in the beginning, but from the beginning he envisages something not perceived by the unimaginative; sights unseen, flights unflown, creations unformed—meaningless to the stolid brain—are real and vivid to the artist, whether he works with brush, with chisel, with pen or with the tools of the laboratory. That is just the difference between the artist and the artisan; one walks by faith and the other by sight. The situation of the imaginative scientist is not unlike that of Michelangelo who saw the figure imprisoned in the block of marble and could not rest until he had set it free. Of such a scientist it has been said, "He is glad if his discoveries can contribute to man's economic welfare and material comfort, but he believes that the chief contributions of science to civilization are its effects on thought and conduct."[1] He is exultant when his discovery is harnessed, but it is very discouraging to be called on to prove the "use" of a recondite idea in advance. What the scientific devotee wants to do is to advance science beyond its known applications and let it find its field of operation for itself; it is quite sure to do that, it runs no risk, there is no manner of doubt that it will prove of service eventually; to-day the highest tributes of praise are being paid to the greatest genius, the most widely distinguished and the least known of American scientists, Josiah Willard Gibbs.

[1] Professor E. P. Lewis, *The University of California Chronicle*, July, 1926.

SCIENCE IN RUSSIA TO-DAY

By Professor WILLIAM SEIFRIZ

UNIVERSITY OF PENNSYLVANIA

RUSSIA, for many of us, is a vast expanse of territory extending from eastern Europe to China; a land covered with snow the greater part of the year and traversed only by sleighs, drawn by horses with queer wooden yokes and followed by wolves; a country notorious for its cold, desolation, czars and prisoners of exile. To be sure, we have heard of large cities, such as St. Petersburg and Moscow, but these heighten rather than soften the awe-inspiring picture which Russia presents, for in St. Petersburg have lived the czars in whose names awful things have been done, and Moscow conjures up in our minds the vision of a starving and retreating army. Recent events have added to the tragedy of Russian history. Revolution has recurred with an intensity and an after-effect surpassing all previous outbreaks, and stories of great suffering and sacrifice have been told us.

It is only natural that our opinion of science in Russia to-day should fit in with our conception of Russia as a whole. It is reasonable to believe that Russian science has suffered the same vicissitudes as have the government and the people. To a degree this is true, but much less so than is generally appreciated. The doubts which have been expressed on both the quantity and the quality of Russian science are as ridiculous as were the similar doubts expressed on German science during the great war. We heard that the science of the Germans was not to be trusted since it was all done with but one motive, the glory of the Vaterland. One wonders if Strasburger had the Vaterland in mind when he had a large oak tree held upright while it was cut at the base and transferred bodily to a vat of staining solution to determine the path of ascending sap, or that Fischer was solely interested in increasing the power of the German empire when he succeeded in synthesizing sugars, or that Pfeffer thought his measurements on osmosis would enhance the chances of success of Germany in the next war. These same jealous haters of humanity are to-day the enemies of Russia. Just such statements as were made of German science during the war are now applied in an altered form to Russian science. "Why go to Russia? Nothing is being done there. No one can possibly work under present conditions. The Soviet Government has no interest in science, art or any intellectual activity." The truth, and some there is, which exists in these statements, is slight. It is my purpose here to present quite a different picture of science in Russia to-day. In so doing I in no way wish to convey the impression that our comrades in Russia have not lived through most trying times—they have, and I shall refer to their suffering—and I do not forget that many of our colleagues have gone to other lands or to another world, and that those still remaining are working under a great handicap; nor do I wish to justify the existence of the present régime in Russia (any more than I should care to seek some ground upon which to justify the existence of the old government). It is my intention simply to state precisely what I saw and heard in the land of the Russians, and if I glorify science in Russia to-day it is solely because of the quality of the work and the courage and fortitude with which it has been done.

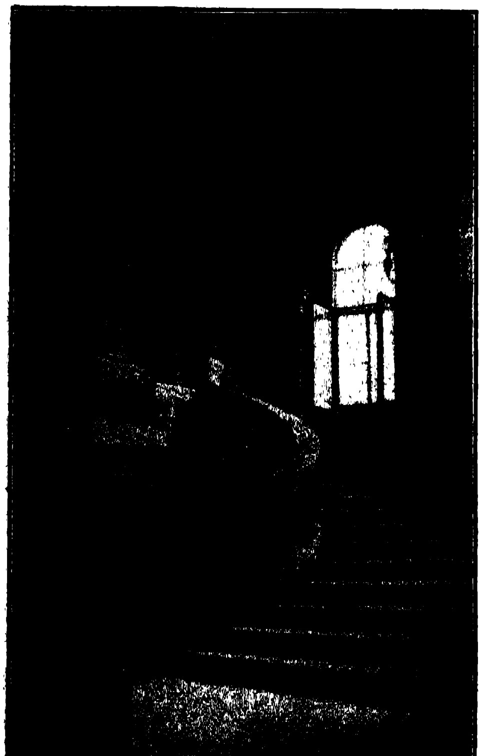
VOSKRESSENIE NA KROVI
ALEXANDER II WAS ASSASSINATED ON THAT PART OF THE WALK TO THE LEFT, NEAR THE IRON RAILING, WHICH IS NOW ENCLOSED WITHIN THE CHURCH BUILT IN HIS HONOR.

There has been no cessation of scientific research in Russia either during the war or after it. While the war was on, some, the botanists, for example, found it more advantageous to continue work in an isolated place such as Tiflis—and what botanist would not seize with delight the opportunity to study the flora of the Caucasus. But whether in far Georgia or still in the home laboratories at St. Petersburg or Moscow, research continued throughout the war. Then came the trying years of 1918 to 1921 when the college professor and his wife stood shoulder to shoulder with the street laborer in line for hours waiting for their apportionment of bread and fish. Still research went on.

The graph at the national herbarium shows a gradual decrease in the number of plants added until 1920. The previous year, 1919, saw the low ebb of the revolutionary tide. The winter was extraordinarily severe. The old and the weak succumbed. Food was sufficient only, as my Russian friends expressed it, "for healthy people not to die." Teaching and research still continued but in classrooms and laboratories where the temperature fell below 0° C.

Since 1920 scientific activity in Russia has been steadily on the upward trend. The herbarium chart again illustrates this. The curve indicating the number of specimens added annually to the national plant collection goes rapidly upward from 4,000 in 1920 to 6,000 in the next year, then to 36,751 in 1925; 60,968 in 1926; and 90,650 in 1927.

The two factors responsible for the



THE HOUSE OF SCIENTISTS IN LENINGRAD
FORMERLY THE PALACE OF GRAND DUKE VLADIMIR, UNCLE OF THE CZAR, AND NOW A DORMITORY FOR VISITING SCIENTISTS

success of Russian science during the last ten years has been the superb spirit of our colleagues there and the excellent support which the communistic government has given them. To those of us who have heeded foreign propaganda—and there is no information which is more maliciously untrue than war-time propaganda—it is a great surprise to learn that the Bolsheviks have encouraged science and art as far as it has been financially possible for them to do. I had heard that the superb collection of paintings in the Hermitage had been pillaged, yet I found this gallery of art complete and well cared for. Some private collections have, to be sure, been lost or destroyed, but the national galleries are intact. I might here add that if an excuse to visit Russia is sought, the collection of paintings in the Hermitage and in the National Gallery of Russian art, formerly the gallery of Alexander III, would justify any one for making the journey to Leningrad. It may be nothing short of sacrilege to say so, but these two galleries combined surpass, in painting, even that mother of all art collections, the Louvre.

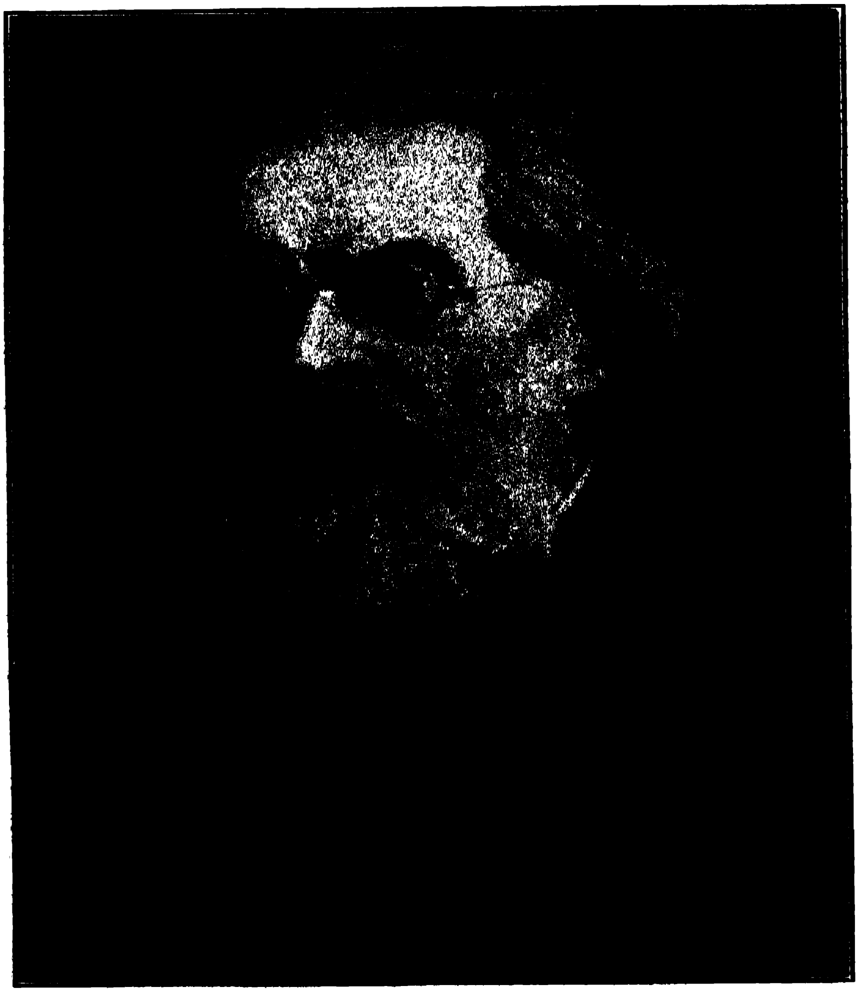
I had also heard that religious worship was prohibited, that all priests had been exiled or executed, and the churches destroyed or converted into schools. Great, therefore, was my surprise when I heard church bells ringing on my first morning in Leningrad; and I later found the little cathedral well filled at mass. The particular church in question is the jewel of all houses of worship in Russia, not in historic value, but in Byzantine splendor of form and color. It is the church "Voskressenie na Krovi," literally "Resurrection on Blood," the blood being that of Alexander II, who was assassinated here in 1881, the cathedral having been built around the spot where he fell. Religious worship is not a part of the communistic creed, but the government permits it. Indeed, to rob the Russians of their religion would be impossible. Religion forms a more intimate part of the lives of the Russians than any other Christian people.

While the Soviet government does not support religious worship, yet it has preserved and cared for all objects of a religious nature where these are of historic or artistic value. But it is the government's support of science in which we are primarily interested.

The first proof which I had that all activities in Russia, academic as well as political and commercial, are under government control and support was the "House of Scientists" to which I was escorted on my arrival and which remained my resting place at night during my sojourn in Leningrad. This building was the former palace of the Grand Duke Vladimir, uncle of the Czar. The house is now a dormitory for visiting scientists. My room was the library and commanded an impressive view across the Neva river with the Peter-Paul fortress—the bastille of Russia—just opposite. Over my cot hung a portrait of Lenin and in the corner stood two red banners. The palace has been pretty well stripped of its valuable furnishings, but its architectural beauty remains. Especially fine is the stairway leading to the grand ball room.

Among the world-renowned treasures of Leningrad is the Botanic Garden with its mile of greenhouses and its herbarium of 3,000,000 specimens which represent 95 per cent. of the world's species of plants. This collection closely approaches, and in certain groups surpasses, in number the famous collections of Kew and Berlin. Professor Issachenko is director of the Gardens.

At the university, the botanical laboratories compare well, both in size and the amount of work being done there, with those of any other institute of learning; indeed, the department of botany at the University of Leningrad surpasses those of some of our leading American univer-



PROFESSOR IVAN P. BORODIN
DEAN AMONG RUSSIAN BOTANISTS

sities. This fact leads me to venture a remark about botany departments in general.

A visiting Swiss scientist recently had pointed out to him the botany building on the campus of one of our American universities.

"Yes," said our guest, "I should have known that that was the botany building without your having told me."

"But how?" we inquired.

"Because it is the oldest building I can see anywhere."

When then asked why it was that the botany department of most colleges is usually shoved into a corner, as exemplified in several leading universities of this country, the Swiss answered the question by saying, "Because we botanists won't fight." Was this the confession of a fault or a virtue? Farlow once expressed a phase of this situation in a humorous way when he gave the following opinion of a just published textbook of biology, "Well, the book seems to me to be mostly about the lobster with not enough lettuce in it to make a decent biological salad."

Among Leningrad men of science those who stand out as preeminent are Pavlov in human physiology, Karpinski in geology, Borodin in botany, Vavilov in genetics, and Maximow and Kostychev in plant physiology. The veterans of this group are Karpinski and Borodin.

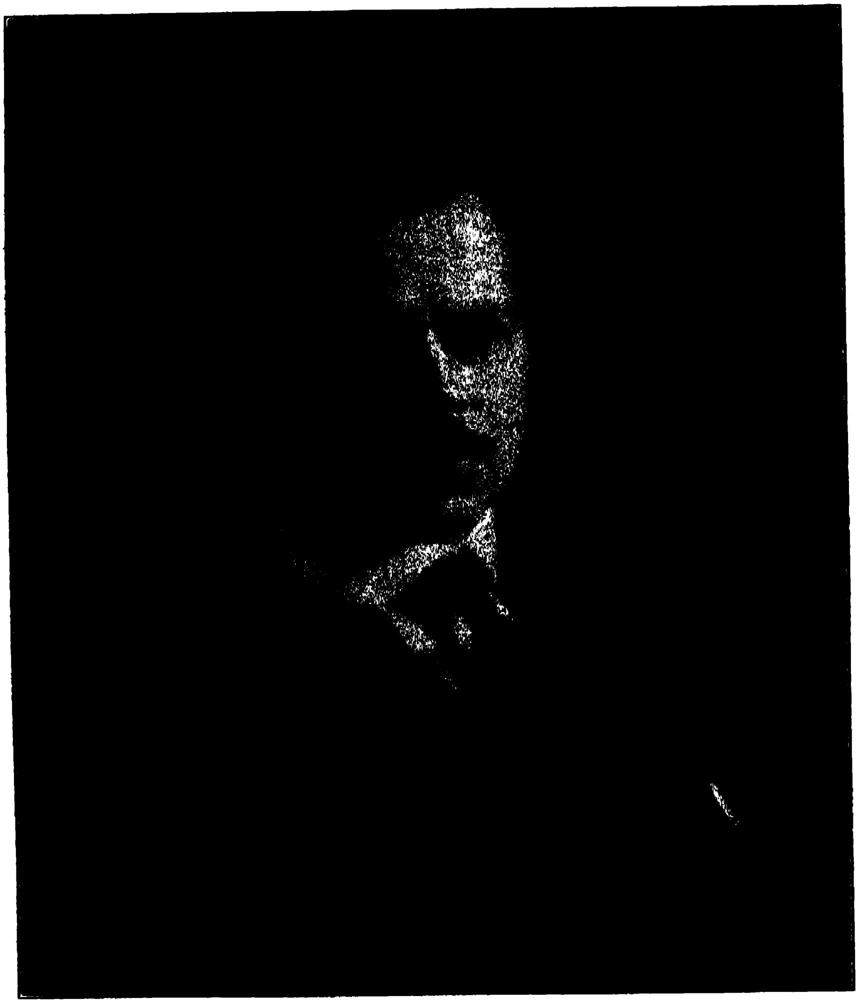
The grand old man of academic botany in Russia is Professor Ivan Borodin. While no longer engaged in university work he is, at the age of eighty-four, still very active mentally. It is a joy to meet him, to join in his good humor and to hear his animated conversation. The events of the last ten years have not in the least broken his spirit. When I asked of others just what position he held among Russian botanists, I was told that, "what Coulter is for America, Borodin is for Russia."

While at the university one should not fail to visit the most sacred room of this time-honored institution, the laboratory of Mendeléeff.

When the prejudices and petty jealousies of those who are living irritate and sadden us, and the joy of work is lessened, the best restorer of our waning enthusiasm is a pilgrimage to the homes and the workshops of the masters who have gone before. Standing in the shadow of their greatness we forget our little difficulties and remember only how fine a thing it is to have added to the advancement of science.

There is no better way to become acquainted with a people than to mingle with the younger generation. Adults, especially if life has handled them severely, soon acquire a crusty exterior which permits little of this real character to seep through. Children, on the other hand, are like books and reveal their true inner selves. One can, therefore, never say that one knows a country unless one has mingled with the younger folks.

University students in Russia seem to be in a state of perpetual good humor, a fact one constantly marvels at when realizing how little they have of even the necessities of life. Poor clothing, simple food and painfully plain living have not dampened their spirits nor made them ill-humored. The gracious attitude which Russian students assume in the presence of a stranger delightfully illustrates one of the outstanding traits in Russians, courtesy to a visitor, a trait which one would like to see many another European people emulate! I was introduced as a professor from the United States who had come to far-off Russia to see how Russian students compared with his own. The girls and the young men instantly arose to their feet, smiled and bowed and expressed the hope that I would judge them kindly, adding that they were undoubtedly not as well clad as American students nor as bright, but that perhaps they did not compare very unfavorably.



DR. N. J. VAVILOV
GENETICIST, DIRECTOR OF THE INSTITUTE OF APPLIED BOTANY

Another charming feature of student life in Russia is the somewhat intimate and affectionate relationship which exists between student and professor as illustrated in the custom of calling the professor not by the usual formal title of "Professor" prefixed to his last name, but by his two first names, "Nicolai Alexandrovitch" (Nicholas the son of Alexander).

Research in botany, agriculture and plant breeding exceeds that of the other sciences in Russia since the nation's present problems are primarily ones of food. The same emphasis is laid upon industrial rather than theoretical research, in chemistry for example, as we shall see in Moscow. Yet pure science is keenly pursued by a smaller though active and capable group of men.

The foremost organization in Russia devoted solely to research in the botanical sciences is the Institute of Applied Botany, with its central office in Leningrad and its chief experimental laboratories at Detskoje Selo. The latter is a little village near Leningrad which formerly bore the name of Tsarskoje Selo. It was the summer home of the last Czar, and also of the great Katherine, and of Paul I. To depart again from science for a moment let me remark that the palace of Katherine II at Detskoje Selo is exquisite, surpassing that of Maria Theresa at Schönbrunn, and equalling, if it does not in sheer beauty surpass the palaces of Versailles. What a contrast exists between the royal splendor and artistically planned palace of Katherine II, at Detskoje Selo, with its room of amber walls, its magnificent parquet floors, and its general appearance of refined elegance so befitting a queen, and the bourgeois mid-Victorian decorations devoid of intellectual interest or esthetic taste in the palace of the last Czar, where the walls of the Czarina's bedroom are covered with cheap trinkets of the church, and her sitting-room literally bespattered with the contents of certainly not less than six family albums! Throughout the visit to the summer palace of Nicholas II but two sympathetic notes are struck—and these are more of pity than aught else—one when viewing the photograph of the sweet face of the Czarevitch, and the other when seeing on the Czar's calendar the last sheet which he touched, July 31, 1917, the night when he and his family were hurried off to Siberia.

The scientific director of the Institute of Applied Botany is the energetic Vavilov whose own particular field of research is genetics and plant breeding. Vavilov is a man of extraordinary activity and enthusiasm which he instills into all who are associated with him. Codirector with Vavilov is the communist Kogan (Russian for Cohen). All government institutions have two directors, one in charge of technical work and one in charge of the government's interests, and in all instances where I made definite inquiry, I was informed that the communistic director in no way hampered or interfered with the proper functioning of the scientific activities of the institution.

Most interesting experimental research is being done by the department of applied physiology, of which Professor Nicholas Maximow is director. He is assisted by Mrs. Maximow, who is also professor of botany at the school of pharmacy. The laboratories of the department of applied physiology are at Detskoje Selo housed in the villa of the Grand Duke Boris, which was erected for him by his godmother, Queen Victoria. The boudoir table in the former duke's home is now a chemical hood, his bureau has been converted into a laboratory table, and the billiard table is being used for sorting and counting seeds from experiments in genetics. It was perhaps a little severe on the duke to have put him out of house and home and country, if indeed his life has not been sacrificed,

PROFESSOR NICHOLAS A. MAXIMOW
DIRECTOR OF THE DEPARTMENT OF APPLIED PHYSIOLOGY AT LENINGRAD AND DETSKOJE SELO

yet one can not help but feel that his villa is serving a better purpose now. The Grand Duke Boris has a brother Cyril, who is now in Paris and is one of the pretenders to the Russian throne.

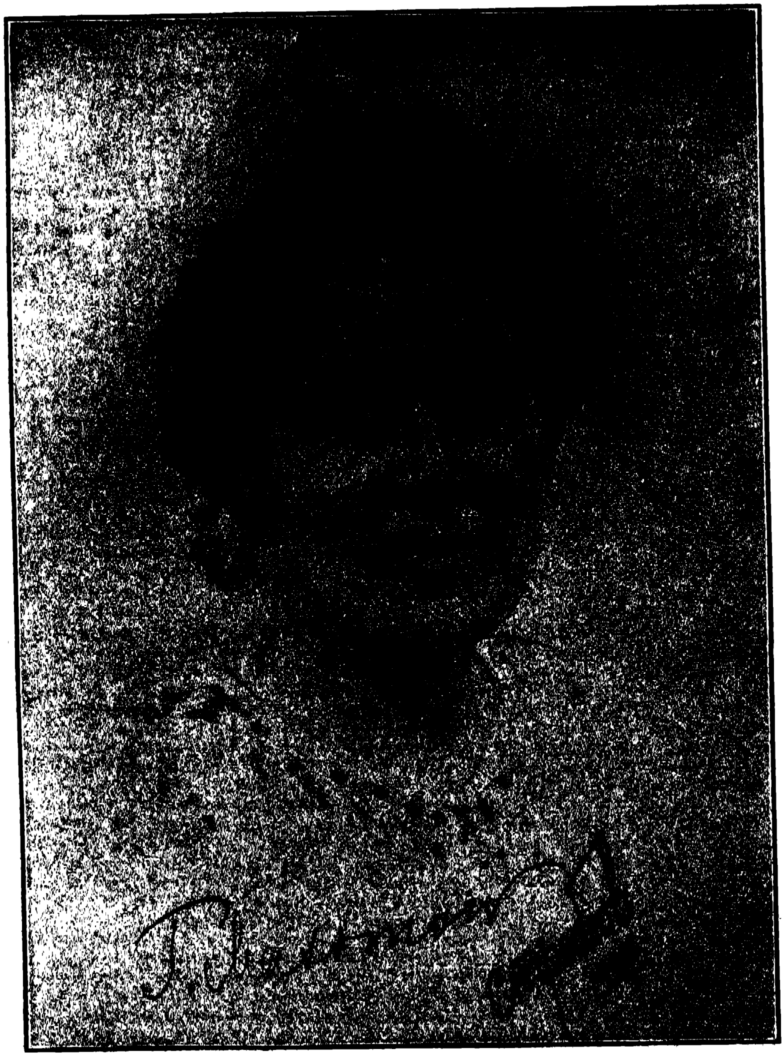
Among the outstanding experiments being carried on in the physiological laboratories at Detskoje Selo are those on the photoperiodism of plants, the equipment for which surpasses that of any other research institute except the Department of Agriculture in Washington. Of value also is the work being done on the physiology of root systems. The experiments are in charge of Mrs. Krassovsky.

Mrs. Maximow and Mrs. Krassovsky, both of whom are doing good scientific work, are examples of the prominent part which the women of Russia are playing in the affairs of their country. The communists believe in the equality of the sexes. The majority of women, married and unmarried, are employed. The customs official in charge of the border station at Ostrov is a woman. The chairman of the committee on foreign relations in Moscow is Trotsky's sister.

Another interesting experiment carried on at Detskoje Selo, by Dr. Karpechenko, is a successful cross between a radish and a cabbage. What the offspring are to be called has not yet been determined. Some of them have temporarily been given such awe-inspiring names as "hypohexaploid hybrid" (because they have fifty-one chromosomes, less than the basic number of nine). The progeny resemble the paternal side more than the maternal. The cross between *Raphanus sativus* and *Brassica oleracea* is about as wide a one as any yet recorded.

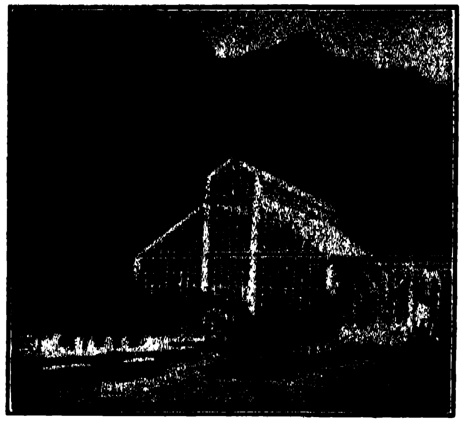
Among other scientists of note in Leningrad two stand out as preeminent among Russian scholars of to-day. These are the great Pavlov, widely known for his work on "conditional reflexes," and

THE EXPERIMENTAL PLOT OF RADISH × CABBAGE HYBRIDS OF THE SECOND GENERATION AT DETSKOJE SELO



MRS. N. A. MAXIMOW
PROFESSOR OF BOTANY AT THE SCHOOL OF PHARMACY, LENINGRAD

LABORATORY OF THE DEPARTMENT OF APPLIED PHYSIOLOGY AT DETSKOJE SELO
FORMERLY THE VILLA OF GRAND DUKE BORIS



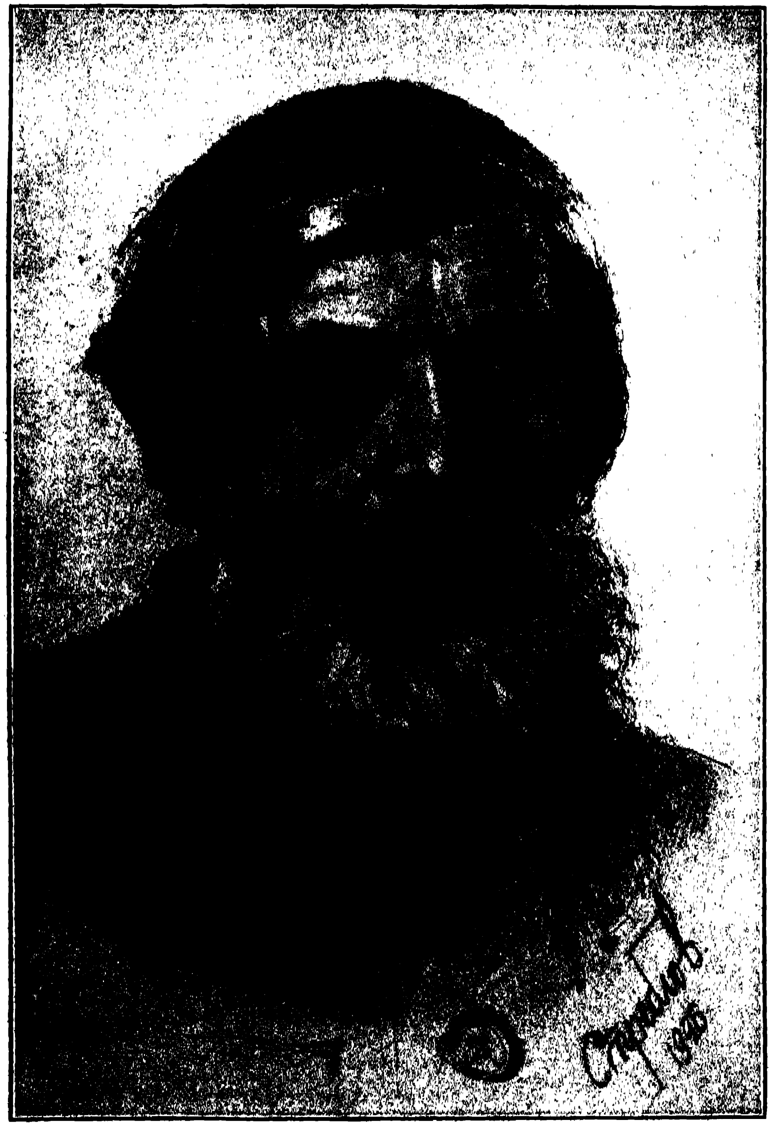
EQUIPMENT FOR EXPERIMENTS IN PHOTOPERIODISM AT DETSKOJE SELO

the geologist Karpinsky, president of the Academy of Sciences at the age of eighty-two years.

An interesting character among men of science is Kovalevsky, director of the Institute of Agronomy, who has the extraordinary distinction of being a highly honored employee of the Soviet government, even though formerly Minister of Finances of the Czar.

The retention of Kovalevsky in a scientific position of importance is an example of the occasionally evident far-sightedness of the Bolsheviks, for which we must give them credit, whatever shortcomings they may have. They realize that a man like Kovalevsky is of value to the country, especially in so important an economic subject as agronomy, and they, therefore, retain

MRS. KRASSOVSKY AND HER ASSISTANT
AT WORK ON THE PHYSIOLOGY OF ROOT SYSTEMS



THE LATE PROFESSOR VLADIMAR BECHTEREV, PSYCHIATRIST

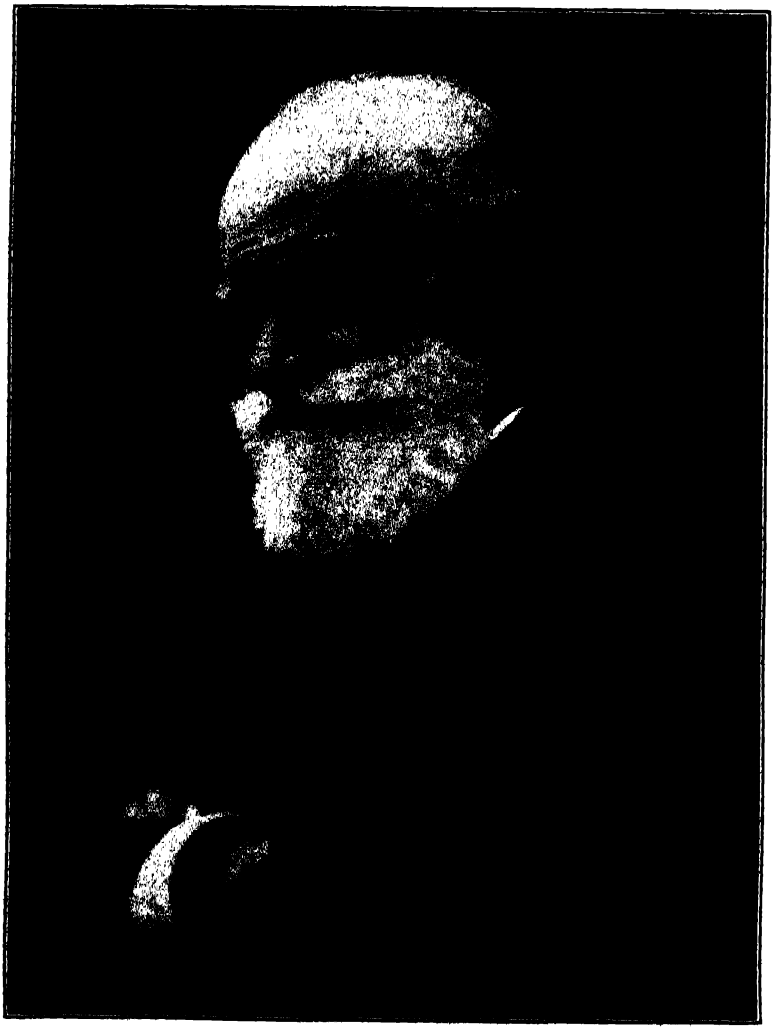
him even though he exemplifies the old aristocracy. Kovalevsky is, in his turn, discreet enough to devote his attention solely to matters of science. This policy of the present government is interestingly and somewhat amusingly shown in those cases where the government has confiscated private collections of old religious paintings, ancient manuscripts, and the like. Realizing that the former owners of these collections are the only ones capable of studying them and properly caring for them, the government has confiscated not only the collections but the owners as well, with the result that the latter still live with their treasures, but now as employees of the government!

Vladimar Bechterev, professor ot psychiatry, is the last scientist of Leningrad to whom I wish to refer. Bechterev gained some notoriety of late from his plan to establish a "pantheon" or museum of brains of deceased Russian men of note. Only recently he, too, passed into the great beyond, having dedicated his brains to the museum which he established. I mention Bechterev not because of his scientific prestige but because of his physiognomy! I purchased Bechterev's portrait since he represented for me the storybook type of Russian whom one would expect to find seated in one of those sleighs racing across snow-covered Siberia followed by wolves to which I referred!

Though we are primarily interested in men of science it is only right that we stop a moment and praise the work of the eminent Russian artist whose portraits of Professor and Mrs. Maximow and of Bechterev we are producing. Streblow was a portrait painter of note during the régime of the last Czar, members of whose family he has done. While still the recognized leader in the art of portraiture, Streblow's social status has fallen to that of the proverbial, struggling art student. He is now obliged to do a dozen portraits a month in order to eke out a living whereas he formerly did one or two and lived well.

We have heard much in America of the underpaid college professor, of the lack on the part of the public of any great respect for or confidence in the university teacher, and of the relatively low social standing which the professor and his family occupy. It is therefore of vital interest to know that these conditions are in all respects reversed in Russia to-day. Those whose social status is the highest, those who are the best paid (with a few exceptions) and the most highly respected are the academicians. It is nothing short of a miracle, which only Russia could have accomplished, that has, literally over night, made the scientist the upper man of the community both in wealth and social standing. At the gala performance of the opening of the opera season in Leningrad the most distinguished person present was the geologist Karpinski.

For the first time in modern history the professor's salary is near the top. The young assistant-professor in Russia receives one hundred rubles ($50.00) a month. The under-official in the government receives not more than one hundred and twenty-five rubles a month. The full professor is paid some one hundred and fifty rubles a month. The highest salary of a valued director of research is four hundred rubles ($200.00) a month. The approximate maximum salary of any government position is six hundred rubles ($300.00), which is drawn only by those few who occupy the highest positions. The stenographer's salary is from eighty to one hundred and forty rubles. The lower incomes permit one individual to live without want. Where a man is married, his wife is either also employed or he holds teaching positions in two institutions. The higher salaries allow a fair degree of comfort. Luxuries, with the exception of the theater, without which no Russian can happily live, are seldom indulged in,



PROFESSOR IVAN P. PAVLOV
DIRECTOR OF THE INSTITUTE OF EXPERIMENTAL MEDICINE, LENINGRAD

and by luxuries I refer to a summer's vacation or a full-course dinner. Such extravagances are all but unheard of.

The student leads a life of extreme economy, yet he has not allowed his poverty to alter materially his naturally friendly and happy disposition.

The average student must exist on twenty rubles ($10.00) a month (paid by the government) and he does it in this way; three rubles a month for his room, which he shares with a comrade, supplying his own blankets and pillow; six kopeks (three cents) a day for one and one-half pounds of black bread for morning and night—the cost of tea to drink with the black bread can be spared, since there is, after all, no nourishment in tea, therefore, hot water will do just as well—twenty-five kopeks a day for half the cost of a fifty kopek dinner, the dinner to be shared with a comrade; three rubles a month for laundry and baths; this leaves less than five rubles a month for books, shoe-repair and theater. No item has been included for clothes. Few clothes are bought. Old ones are patched and repatched, but if money is needed for this purpose the student can earn it by extra work at the docks. If a student is missing from class no questions are asked, since it is taken for granted that he or she is at the docks. This poverty and deprivation is endured without complaint.

Before leaving Leningrad a brief visit should be paid to the National Library, where Dr. Rimsky-Korsakow will show us about. Dr. Rimsky-Korsakow is the son of the famous composer of the same name. The former Imperial Library in Leningrad is something more than a mere collection of books. There are many fine engravings, including a collection of portraits of Paul I, and some oil paintings, notably a large canvas of Katherine II. Especially fine are the old manuscripts and early editions of books, which include several very rare Bibles. These early editions are housed in a small room built after the manner of an imaginary studio of Faust which gives quite the appropriate atmosphere for ancient writings. This quaint room "à la Faust" is known as the Division of the "Incunables," namely, the division housing books edited not later than 1500. Among other treasures is the Gutenberg or Masarinov bible.

One leaves Leningrad with a new conception of Russia, for one has discovered art there which surpasses that of other world cities; palaces whose richness and beauty are not elsewhere to be found; library facilities the like of which few nations can boast; and an activity in scientific research that is extraordinary in the face of what Russia and her people have suffered.

The peaceful state of Leningrad belies all reports of the unsettled, lawless condition of the country. The city is as quiet and as orderly as one could desire. When one compares the village-like peace of Leningrad with the noises and horrors committed *and tolerated* in New York, Philadelphia and Chicago, one wonders if it is Russia or our own country which needs looking after the more.

Moscow and Leningrad differ in almost every conceivable respect. Leningrad is a quiet, conservative, residential city, dominated by the activities of men of science, letters and art, a new city famed for its institutions of learning, its collections of paintings and its palaces. Moscow is a noisy, progressive, commercial and political city, dominated by the activity of government officials and men of trade and commerce, an old city famed for its ancient walls and churches. There is considerable rivalry between the two cities, a Leningradian is unhappy in Moscow and never goes there unless he is forced to, while a Moscovian avoids Leningrad as a New Yorker does Philadelphia!

A similar marked difference in the type of scientific work done in the two cities is noticeable. Research in Moscow tends more toward the practical and commercial, in Leningrad more toward

the academic. We thus find in Moscow twenty institutions of industrial chemistry and technology out of a total of thirty in all Russia. It should not be assumed, however, that academic research work is at a standstill in Moscow. On the contrary, the department of botany at the university, where Professor Michael Golenkin is the senior member, is quite active. There is also the Timiriasev Federal Institute of Scientific Research, small to be sure, but having such eminent workers as the cytologist Nawashin and Professor Alexander Kiesel, whose work on the chemistry of protoplasm is the best yet done. More pretentious are the several institutes of biology and chemistry, of which Alexis Bach, best known for his work on oxidases, is director. These are the Karpow Chemical Institute, the Bach Biochemical Institute and the Institute of Experimental Biology.

At the first-mentioned institute of industrial chemistry every effort is being extended to make Russia independent of the world in her needs in technical products, thus, the research on dyestuff is especially active. An adjoining laboratory has succeeded in producing a bakelite which is said to be superior to the American product.

Moscow is a city half of the orient. Its ecclesiastical architecture is Byzantine, its people phlegmatic and its beggars classic. More picturesque mendicants are not to be seen anywhere, especially the street urchins—delightfully happy little rascals they are. When I objected that I did not have sufficient kopeks to divide among so many, one replied, "Oh, that is all right, we are working together!" But the story of these lawless ragamuffins is a tragic, not a happy one.

Intellectual activity in Russia, while centered in Leningrad and Moscow, is not restricted to these metropoles. Kiev, Charkov, Odessa, Rostov, Minsk, Perm, Tomsk, Vladivostok, Baku, Tiflis, Saratov, Kazan and several other cities, including far-off Tashkent, have their universities.

One can not visit the land of the Russians, accept the gracious hospitality of the people, share in the enthusiasm which they have in their scientific work and observe with what patience and good humor they bear their hardships, without departing with every feeling of sympathy and good will. There may exist differences of opinion on the advisability of our or any other country recognizing the Soviet Government, but the question whether American men of science should recognize their colleagues in Russia, and interest themselves in the needs of Russia science, has but one answer. To speak ill of Russia and the Russians is to speak in ignorance.

A STORY OF THE RISE OF A SOCIAL TABOO

By Professor KIMBALL YOUNG

UNIVERSITY OF WISCONSIN

I

To expose the origin of a social taboo is to reveal an important factor in social control. It is the purpose of this paper to trace the rise of a group taboo in a pioneer society in western America. The particular example will be that of the rise of the taboo on the killing of a gull among the Mormons in the early days of their settlement in Utah.

The first group of Mormons, 143 in number, arrived in the valley of the Great Salt Lake on July 24, 1847. Some small tracts of land were put under irrigation within a few weeks. Throughout the summer additional "companies" of pioneers arrived and before autumn considerable land was brought under cultivation. By the spring of 1848, the colony was fairly well established. Whitney, in his "History of Utah," describes the situation as follows:

> The opening of the spring of 1848 in Great Salt Lake City saw nearly seventeen hundred souls dwelling in upwards of four hundred log and adobe huts inside the "Old Fort." Over five thousand acres of land had been brought under cultivation, nearly nine hundred acres of which had been sown with winter wheat, the tender blades of which were now beginning to sprout.

Naturally the strain on the food supply had been very severe during the winter of 1847–1848 and the settlers were thoroughly dependent for survival upon the forthcoming harvest of 1848. Their remoteness from outside sources of food supply was obvious. And during the summer of 1848 hundreds more of Mormons arrived from the Missouri River region, which but added to the demands on the food resources for the coming winter.

In May and June of 1848 large numbers of crickets (*Anabrus simplex*) began to appear in the wheat fields. At first little attention was paid to these pests, but as time went on they increased in number and in the damage they did to the growing crops. Mr. Anson Call, one of the Utah pioneers, gives the following pious but amusing description of the insect:

> The Rocky Mountain Cricket, as now remembered, when full grown is about one-an-a-half inches in length, heavy and clumsy in its movements, with no better power of locomotion than hopping a foot or two at a time. It has an eagle-eyed, staring appearance, and suggests the idea that it may be the habitation of a vindictive little demon.

The crickets made another intense crisis for the already much harassed Mormons. Removed both by distance and by prejudice from assistance, the very existence of the group seemed at the time to be threatened. Every effort was made to drive off the pests. Whitney writes of the period:

> With the energy of desperation, the community, men, women and children, thoroughly alarmed, marshalled themselves to fight and if possible to repel the rapacious foe. While some went through the fields killing the crickets, and at the same time, alas! crushing much of the tender grain, others dug ditches around the farms, turned water into the ditches, and drove and drowned therein myriads of the black devourers. Others beat them back with clubs and brooms, or burned them in fires set in the fields. Still they could not prevail. Too much headway had been gained by the crickets before the gravity of the situation was discovered, and in spite of all that the settlers could do, their hopes of a harvest were vanishing, and with these hopes the very hope of life.

The pressure of hunger became very real. One of the settlers, Parley P.

Pratt, thus describes the hardship of his family:

> During this spring and summer my family and myself, in common with many of the camp, suffered much for want of food . . . We had lost nearly all our cows, and the few which were spared to us were dry . . . I had ploughed and subdued land to the amount of nearly forty acres . . . In this labor every woman and child in my family, so far as they were of sufficient age and strength, had joined to help me, and toiled incessantly in the field, suffering every hardship which human nature could well endure. Myself and some of them were compelled to go with bare feet for several months, reserving our Indian moccasins for extra occasions. We toiled hard and lived on a few greens, and on the thistle and other roots.

The writer has been told by persons who lived through this period that the domestic fowls of the households devoured such quantities of the crickets as to make their eggs quite unpalatable, thus cutting off a minor source of food. Furthermore, the crickets attacked the small grazing lands available for live stock, thus adding another burden to the major one.

Now the nearby Paiute Indians found in these very crickets a pleasant delicacy and ate them in large numbers. But the food-habits of the white man prevented a sensible adaptation to the Indian usage. Differences in culture make differences of tastes.

The Mormons, like all people of primitive culture status, confused natural with supernatural or magical practices. And while they made untiring attempts to combat these pests, they also resorted to prayer and magic for release from the strain and problem. Man confronted with the futility of his own efforts seems to resort to supplication or to magic, or both, to obtain his desires. So, here, entreaties were made for divine intervention to free them from this plague. The following Mormon account gives at once the essential facts of the situation and also the settlers' rationalization of the event:

> They were saved, they believed, by a miracle. . . . In the midst of the work of destruction, when it seemed as if nothing could stay the devastation, great flocks of gulls appeared, filling the air with their white wings and plaintive cries, and settled down upon the half-ruined fields. At first it seemed as if they came but to destroy what the crickets had left. But their real purpose was soon apparent. They came to prey upon the destroyers. All day long they gorged themselves, and when full, disgorged and feastod again, the white gulls upon the black crickets, like hosts of heaven and hell contending, until the pests were vanquished, and the people were saved. The heaven-sent birds then returned to the lake islands whence they came, leaving the grateful people to shed tears of joy at the wonderful and timely deliverance wrought out for them.

Bancroft, in his "History of Utah," reports that later in the same season grasshoppers or the "migratory" locusts (*Melanophus spretus*), did considerable damage to the remaining crops. And the next year the crickets appeared again, although not in such numbers. This, coupled with drought and frosts, made the second year almost as severe as the first. From time to time during the next ten years the pioneers had to combat both crickets and grasshoppers. In 1854 and in 1855 the crops failed due to the grasshoppers. This reduced the group to straitened circumstances and in these years the gulls did "not come to the rescue."

Yet for the year 1848 the "miracle" of the gulls meant survival. Naturally much significance was attached to their visitation. The superstitious pioneers gave thanks to their god for deliverance from threatened disaster. The crisis of famine had been met successfully by what seemed divine intervention. The crops were harvested and though not bounteous were sufficient to see them through the coming winter. The harvest festival which was held is typical of a group-response to this happy solution of a serious crisis. Bancroft writes:

> On the tenth of August, however, the harvest being then gathered, a feast was held in the

bowery (a community structure for religious services), at which the tables were loaded with a variety of viands, vegetables, beef, and bread, butter and cheese, with cakes and pastry. Sheaves of wheat and other grain were hoisted on harvest poles; and [says Parley P. Pratt] there was prayer and thanksgiving, congratulations, songs, speeches, music, dancing, smiling faces, and merry hearts. . . .

The Mormons naturally developed a high reverence for the gull. Songs were sung, poems written, sermons and personal "testimonies" given concerning the supernatural deliverance. The bird became a sacred object to these people. The territorial government which was organized shortly thereafter and which was completely Mormon in composition, passed legislation prohibiting the killing of the gull. The official Mormon historian, Mr. Whitney, gives the following panegyric on the birds:

Is it strange that among the early acts of Utah's legislators there should be a law making the wanton killing of these birds a punishable offense? Rome once had her sacred geese. Utah would thenceforth have her sacred gulls. Ye statesmen and state-makers of the future! When Utah's sovereign star, dawning above the dark horizon of factional strife, shall take its place in the blue, unclouded zenith of freedom's empyrean, and it is asked by those who would frame her escutcheon, what shall her emblem be? Name not at all the carpet-bag. Place not first the bee-hive, nor the eagle; not yet the miner's pick, the farmer's plow, nor the smoke-stack of the wealth-producing smelter. Give these their places, all, in dexter or in middle, but whatever else the glittering shield contains, reserve for the honor point, as worthy of all praise, the sacred bird that saved the pioneers.

While the Mormon statesmen did not heed Mr. Whitney's suggestion, the gull incident has continued to play a very large part in the folk-lore and history of the state. And as a final culmination to this development, as an artistic rationalization, has come the erection of the "Sea-gull Monument" in Salt Lake City, showing atop a shaft of thirty feet or so a golden ball upon which two gulls are placed. Around the base of this monument are four reliefs portraying the coming of the pioneers into the Great Basin, the planting of crops, the contest with the crickets and, finally, the "miraculous" deliverance by the gulls.

II

So much for the story. What as to its meaning for the study of the rise of a social taboo and a folk-lore?

In the first instance, it must be noted that although this religious body drew most of its fundamentals from such creeds as the Campbellites, the Baptists and from the general Puritan tradition, its concepts were decidedly primitive throughout. The belief in direct, divine revelation was basic as was the belief in a divinely appointed priesthood and in miracle-working. The long history of hardship and persecution had produced an intense loyalty and sense of social solidarity. The pioneer life had thrown these people into a distinctly alien and elemental country with a reduction of life to a direct struggle for existence. It is true that they brought with them the material culture of their contemporary civilization which enabled them to till the soil, put irrigation into effect and to construct a more adequate economic life than the Indians around them had. But as to what may be called nonmaterial or psycho-social culture, especially on the side of religious beliefs and notions of magical power and supernatural influences, they were not greatly advanced over the Middle Ages or the peasant peoples of Europe and Asia. As one must recognize at all times, the state of learning and the manner of life are not a matter of time or place but of cultural level. In regard to interpretations of natural phenomena, the Mormons were much inclined to magical thinking.

While their Protestant background prevented the development of a whole series of rituals and public festivals in

reference to the gulls, certainly a rigid, rather superstitious taboo arose concerning them. Furthermore, the rise of the bird to a position of worship as a totem of the group was incipient but prevented by the existence of other culture patterns of more complex sort drawn from their religious and theological background. Still, we may note, in conclusion, how much of rudimentary reaction and interpretation did remain. We may summarize the following stages in the development of this whole culture complex of the gull:

(1) We have a severe group crisis. The food supply is threatened by the pest of crickets. Group survival is at stake.

(2) There is an inability to cope with the situation by any naturalistic means. In other words, common-sense techniques do not suffice to allay the crisis.

(3) There is a turning to God for help. Actually, of course, with these vigorous people there was a combination of work and prayer. Aggressive Christian peoples facing starvation are not apt to forget the injunction to *faith and works*.

(4) There is some delay in the answer to the first entreaties to God for deliverance. Men of that generation of Mormons have been known to say that this occurred "in order to test the faith of the people"—a very typical rationalization. Thus the crisis continues to grow more and more alarming and this in spite of renewed efforts of their own techniques and of additional piety.

(5) There is a growing despair on the part of the group as they see their crops being destroyed. There is great emotional disturbance consequent to this: fear, sorrow, anticipated grief and hardship. No doubt in some skeptical ones there is slight anger at the delay of God in responding to supplications. Certainly there is rage and an unpleasant feeling of balked effort toward the insects.

(6) The rather sudden appearance of the gulls with some perturbation at first that they might also be bent on destroying that which the crickets had not yet devoured. Thus, increased emotional toning is developed, that is, fear and anger toward the gulls that they might assist in the final consumption of the growing crops and thus complete the horror.

(7) The unexpected, the amazing behavior of the gulls in devouring not the crops but the insects. This not in few cases but in great quantities; their disgorging these, so legend has it, and their curious repetition of eating still more crickets. Here we have the surprise turn or climax of a socio-economic drama in real life. Here we see the operation of what Sumner called the aleatory or luck element in social crises.

(8) The saving of the crops, then, led to giving thanks to God who is credited with sending the gulls, not to the gulls directly, since the religious cast of their minds prevented this more primitive response. There was also the verbal testimony in church gatherings about this "miraculous" solution. There is, in short, the religious thrill of deliverance from evil and a return to good. As Sumner puts it:

> The minds of men always dwell more on bad luck. They accept ordinary prosperity as a matter of course. Misfortunes arrest their attention and remain in their memory. Hence the ills of life are the mode of manifestation of the aleatory element which has most affected life policy . . . Good or ill luck were attributed to superior powers, and were supposed to be due to their pleasure or displeasure at the conduct of men . . . The aleatory element has always been the connecting link between the struggle for existence and religion.

(9) Then came the raising of the gull to a place of religio-economic significance and the placing of a taboo upon its destruction. It becomes a sacred object.

Thus we see illustrated the fundamental nexus of religion and socio-economic life witnessed in all rudimentary societies.

(10) There has come a whole local literature, history and folk-lore about the gulls among these people. Thus a legend has grown up about the crisis and its solution. Curious attributes of insight and intelligence have been given them, often quite contrary to fact.

(11) Recently we have a final culmination in an object of veneration and communal attention, if not direct worship, which serves for the group as a rallying point in recall and contemplation of this miracle. That is, we have a monument to the gulls which is a kind of attenuated, amorphous totem pole, something which in more simple cultures might have played a very distinct rôle in the daily religious life of a people.

III

To mention the wider implications from this curious incident: In the first place one notes the importance of disaster or crisis in producing the taboo and the new folk-lore. No doubt a great many of our taboos and methods of social control arose in critical situations not unlike this one in general features. In the second instance, one must recognize the psychological factors in the situation, such as the arousal of intense emotions, the feelings of balked effort and the tendency to superstitious and magical thought processes when the common-sense means failed. Finally, the direction which the interpretation of this experience took was determined by the previous experience, by what the anthropologist calls the culture patterns, of the group. Thus, the development of real animal worship and the making of the gull into a true totem were probably prevented by the existence in the minds of these people of religious and social ideas of a higher and different order from those current in more primitive peoples.

THE WIDER ASPECTS OF COSMOGONY[1]

By Dr. J. H. JEANS

SECRETARY OF THE ROYAL SOCIETY

INTEREST in scientific cosmogony is a recent, and still a very tender growth. Anthropologists and geologists tell us that man has existed on earth for something like 300,000 years; we must go this far back to meet our ape-like ancestry. Between them and us some 10,000 generations of men have walked the earth, most of whom have probably given some thought, in varying degrees, to the significance of their existence and the plan of the universe.

Of these 10,000 generations of men, the first 9,990 unhesitatingly regarded the earth as the center, and terrestrial life as the central fact, of the universe. As was suited to its majesty and dignity as the abode of man, the earth stood still while the celestial sphere spun round it, covering in the earth much as a telescope-dome covers in the telescope; and this dome was spangled with stars, which had been thoughtfully added so as not to leave the central earth unillumined at night. Ten generations at most have been able to consider the problem of their existence in anything like its proper astronomical perspective.

THE POSITION OF MAN IN THE UNIVERSE

The total age of the earth far exceeds the 300,000 years or so of man's existence. The evidence of geology, and of radio-activity in rocks in particular, shows that it must be something like 2,000 million years, which is several thousand times the age of the human race. Old Mother Earth must regard man as a very recent apparition indeed; he has just appeared to burrow into her, burn her forests, put her waterfalls into pipes, and generally mar the beauty of her features. If he has done so much in the first few moments of his existence, she may well wonder what is in store for her in the long future ages in which he is destined to labor on her surface. For in all probability the life in front of the human race must enormously exceed the short life behind it. A million million years hence, so far as we can foresee, the sun will probably still be much as now, and the earth will be revolving round it much as now. The year will be a little longer, and the climate quite a lot colder, while the rich accumulated stores of coal, oil and forest will have long been burnt up; but there is no reason why our descendants should not still people the earth. Perhaps it may be unable to support so large a population as now, and perhaps fewer will desire to live on it. On the other hand, mankind, being three million times as old as now, may—if the conjecture does not distress our pessimists too much—be three million times as wise.

Looked at on the astronomical time-scale, humanity is at the very beginning of its existence—a new-born babe, with all the unexplored potentialities of babyhood; and until the last few moments its interest has been centered, absolutely and exclusively, on its cradle and feeding-bottle. It has just become conscious of the vast world existing outside itself and its cradle; it is learning to focus its eyes on distant objects, and its awakening brain is beginning to wonder, in a

[1] The Trueman Wood Lecture delivered before the Royal Society of Arts on March 7 and printed in *Nature*.

vague, dreamy way, what they are and what purpose they serve. Its interest in this external world is not much developed yet, so that the main part of its faculties is still engrossed with the cradle and feeding-bottle, but a little corner of its brain is beginning to wonder.

Taking a very gloomy view of the future of the human race, let us suppose that it can only expect to survive for two thousand million years longer, a period about equal to the past age of the earth. Then, regarded as a being destined to live for threescore years and ten, humanity, although it has been born in a house seventy years old, is itself only three days old. But only in the last few minutes has it become conscious that the whole world does not center round its cradle and its trappings, and only in the last few ticks of the clock has any adequate conception of the size of the external world dawned upon it. For our clock does not tick seconds, but years; its minutes are the lives of men. A minute and a half ago the distance of a star was first measured and provided a measuring-rod for the universe. Ten seconds ago Shapley showed how the peculiar stars known as Cepheid variables provide a longer measuring-rod, and taught us to think in distances so great that light takes hundreds of thousands of years to traverse them. With the very last tick of the clock, Hubble, using the same measuring-rod, has found that the most remote objects visible in the biggest telescope on earth are so distant that light, traveling 186,000 miles a second, takes about 140 million years to come from them to us.

Not only is our vision of the universe continually expanding, but also it is expanding at an ever-increasing rate. Is this expansion destined to go on for ever? So far as we can at present see, no; for a general guiding principle, that of generalized relativity, fixes a limit, which we are fast approaching. According to this theory, space can not extend for ever; it has no limit, but is nevertheless finite like the surface of the earth. Without exploring and surveying the whole of the earth's surface, we can make a fair estimate of its total area by measuring its radius, which we can do by measuring its curvature at any one point. In the same way the total volume of space is fixed by a quantity, the curvature of space, which can be determined by measuring the density of distribution of matter in space. Space which contained no matter would go on for ever, but the parts of space we can survey with our telescopes contain enough matter to show that we already see an appreciable fraction of the whole of space. It is as though our baby, watching ships coming from over the horizon, concluded that the earth's surface was curved, and formed a general rough conception of its size by imagining the observed curvature continuing until the earth's surface rounded back on itself.

Exact figures are impossible, but Hubble has calculated that space is not likely to extend to more than about a thousand times as far as the farthest nebula visible in the biggest telescope. Nothing prevents our going on and on in space beyond this distance, but, if we do, we merely come back to ourselves. The possessor of a sufficiently sensitive wireless apparatus may emit signals and pick them up a seventh of a second later after they have traveled round the world. In the same way a not inconceivable increase in the size of our telescopes would take us round the whole of space, and we should see the stars surrounding our sun by light which had traveled round the universe, not of course as they now are, but as they were 100,000 million years ago.

Such considerations make it improbable that the expansion of the universe can continue at its present rate for much longer. Having grasped that the world is round, the infant speedily forms a fair idea of its size. Our particular infant, mankind, has made the great discovery of the existence of the outer world, has formed some conception of its size, and adjusted his ideas, not by a process of slow revelation, but by a brain-flash of the last few seconds. In his mature years and his staid old age he is no doubt destined to make many sensational discoveries, but he can never again live through the immortal moment at which he first grasped the immensity of the outer world. We only live through a few ticks of his clock, and fate might have ordained that they should be anywhere in the three days that the child has already lived, or in the seventy long, and possibly tedious, years yet to come. The wonderful thing is that she has selected for us what is, perhaps, in some ways the most sensational moment of all in the life of our race.

The child sets its newly awakened mind to work to adjust and coordinate a new array of facts. If the world was not made to surround its cradle, what purpose can it serve? If the lights of the great ships in the harbor were not designed to light its nursery at night, what can they possibly be for? And, most interesting problem of all, if the world is such a big affair, can there be other cradles and other babies?

These remarks will have served their purpose if they suggest that what I am rashly trying to set forth here should not be judged as a finished science or the solution of a problem; it is rather the first confused gropings of the infant mind trying to understand the world outside its cradle. And if the impression produced by its first inexperienced glance at the outer world had to be described in a single word, it would probably select the word "immensity."

The Immensity of Space

The immensity of space is measured by the figures already mentioned. Light and wireless signals travel at the same rate because, of course, they are essentially the same thing; and this thing takes a seventh of a second to travel round the world, and probably something like 100,000 million years to travel round the universe. The ratio of these times (2×10^{19}) measures the dimensions of the universe in terms of the familiar dimensions of the world; incidentally, it also measures the expansion of our spatial ideas since Copernicus. The disparity of size is too great to be easily visualized. Suppose the size of our earth represented by a single atom. Then the range of vision of the biggest telescope is about represented by the whole earth, and the size of the whole universe, according to the theory of relativity, is represented by a stack of a thousand million earths.

Scarcely less bewildering than the immense extent of space is the immense amount and variety of matter it contains. The sun, which is a million times as big as the earth and 300,000 times as massive, proves to be something less than a grain of sand on the seashore. It forms one of a family whose number must certainly be counted in thousands of millions; Seares has estimated it at thirty thousand millions. This is not the only family of stars in space. Each of the great spiral and other extragalactic nebulae, is either a family of stars, or consists of stars in the making, or of matter which is destined ultimately to form stars. We can estimate the masses of these great nebulae by gravitational means, and each is found to contain enough matter to make a thousand million suns. This of itself will give some conception of the vast size of these

nebulae, but to tell the whole story, it must be added that their colossal masses are so tenuous that each millionth part of an ounce is, on the average, as big as the Matterhorn. Think of a body which is bigger than the Matterhorn by as much as a thousand million suns is heavier than a millionth part of an ounce, and we have the size of any one of these great nebulae. Any one of the three photographs that I have would have to be enlarged so as to cover the whole of Asia before a body of the size of the earth became visible in it at all, even under the most powerful of microscopes.

Hubble estimates that about two million such nebulae are visible in the great 100-inch telescope at Mount Wilson, and that the whole universe has about a thousand million times the volume of that part of space visible in this telescope. Let us now multiply 1,000 million by 2 million, and the product by 1,000 million. The answer (2×10^{24}) gives some indication of the probable number of stars in the universe; the same number of grains of sand spread over England would make a layer hundreds of yards in depth. Let us reflect that our earth is one millionth part of one such grain of sand, and our mundane affairs, our troubles and our achievements, begin to appear in their correct proportion to the universe as a whole.

While the stars may fairly be compared to grains of sand in number, they differ too much *inter se* for the comparison to be carried further. There is an enormous variety of big and little stars, of bright and faint stars, of red and blue stars, and of hot, hotter and still hotter stars. The faintest of known stars (Wolf 359) emits only a fifty thousandth part of the light of the sun, while the brightest (S. Doradus) emits 300,000 times as much light as the sun. The smallest known star (Van Maanen's star) is about the size of the earth; a million such stars could be packed inside the sun and leave room to spare. The largest known star (Betelgeuse) is so large that 25 million suns could be packed inside it. Their ranges are greater than those between a searchlight and a glowworm, or between balloons and bird-shot.

Yet the stars are essentially similar structures. A normal atom consists of a central nucleus round which a number of electrons revolve like planets round the sun—a miniature solar system, in fact, in which the vacant space far exceeds that occupied by matter. With great heat the electrons begin to break loose and fly off at a tangent. The central temperatures of the stars can be calculated with fair precision, and prove to be so high that most of the electrons must have already broken loose from their atoms. Of recent years, a great deal of labor has been devoted to testing the hypothesis that practically all the electrons have so broken loose, the stripped atoms and electrons flying about in a general hurly-burly like the molecules of a gas. But the hypothesis has proved disappointing, and a much more probable hypothesis is, I think, that the atoms are not stripped quite bare, but that in most stars they retain a few rings of electrons which give the atoms so much size that they jostle one another about like the molecules of a liquid. This hypothesis explains beautifully the otherwise puzzling fact that stars of large mass fall into distinct groups, of what may almost be described as "standardized" sizes. On the "liquid star" hypothesis, these different sizes correspond to the different sizes possible for the stellar atoms, which may have 0, 1, 2, or 3 rings of electrons left, but can not have fractional numbers. The largest stars of all, such as Betelgeuse, have three rings left, while minute stars, such as Van Maanen's star, con-

sist of atoms most of which are stripped quite bare, so that there is almost no limit to the closeness with which they can be packed together. An average handful of the matter of which this star is composed would contain about ten tons.

Thus the observed sizes of the stars proclaim the secret of the structure of the atom. The sizes of the stars are discontinuous because the sizes of atoms broken down to different stages are discontinuous. These discontinuities can be traced in turn to the discontinuities which form the central feature of the new quantum dynamics. Thus the distinguishing characteristic of the laws which govern the most minute processes in Nature is transmitted directly into the large scale phenomena of astronomy and governs the distribution of the huge masses of the stars. The infinitely great is never very far from the infinitely small in science, but it would be hard to find a more sensational illustration of the unity of science than that I have just given.

On this hypothesis, not only do the observed sizes of the stars disclose the general structure of the atom, which is old knowledge, but they also reveal the detailed structure of the particular atoms of which the stars are composed, and this is new knowledge. To be precise, the observed sizes of the stars disclose the atomic weights of the stellar atoms; they indicate that the stellar atoms are probably rather heavier than the heaviest atom, uranium, known on earth. The atoms which reveal their presence in stellar spectra are, of course, atoms of the ordinary terrestrial elements—hydrogen, iron, calcium, and the like. These, being the lightest atoms in the star, must naturally float up to its surface, and, as the earth was originally formed out of the surface of the sun, the earth is necessarily composed of them. But it now appears likely that down in the depths of the stars are other unknown and heavier atoms. We may almost say that it must be so, for no terrestrial atoms, not even radium or uranium, can produce anything like the amount of energy which these stellar atoms are observed to produce.

The Immensity of Time

The immensity of space is paralleled by that of time. We can estimate the ages of stars from the impression that time has made upon them, just as we estimate the age of a tree from the number of subdivisions of its stem, or of rings in its cross section. There are three principal methods of doing this. The orbits of binary stars, which are circular at birth, are gradually knocked out of shape by the forces from passing stars. As we can calculate the rate at which this process occurs, the shape of stars' orbits can be made to reveal their ages. The moving clusters provide a second method. Groups of bright stars such as the Great Bear, the Pleiades, Orion's Belt, are often found to consist of exceptionally massive stars which move in regular orderly formation through a jumble of slighter stars, like a flight of swans through a confused crowd of rooks and starlings. Swans, however, are conscious beings, and continually adjust their flight so as to preserve their formation. The swan-like stars can not do this, so that their orderly formation must in time be broken by the gravitational pull of other stars. When this happens, the lighter stars are naturally knocked out of formation first, while the most massive stars retain their formation longest. This agrees with what is observed, and as we can calculate the time necessary to knock out the lighter stars, we can at once deduce the ages of those which are left in. A third method of investigation rests upon a rather abstruse dynamical theorem, which shows that after a sufficient time the energies of motion of the different

types of stars must tend to equality, the little stars making up for the smallness of their mass by the rapidity of their motion. Seares has shown that the stars near the sun have nearly attained to this ideal state, and as we can calculate the time needed to establish it, we can again deduce the ages of the stars.

It is gratifying and significant that all three lines of investigation lead to the same result: the stars are found to be some millions of millions of years old, perhaps from five to ten millions of millions. We can not state their age with much precision, but it is the general order of magnitude, not the exact figure, that is important.

Stellar Radiation

Year after year, century after century, for millions of millions of years, the sun radiates enough energy from each square inch of its surface to keep a 50 h.p. engine continually in action; still hotter stars may radiate as much as 30,000 h.p. per square inch. If this energy were produced by the combustion of coal, the stars would all be completely burnt out in a few hundreds or thousands of years. Where, then, shall we find a source of energy to last millions of millions of years?

More than twenty years ago I directed attention to the enormous store of energy made available by the annihilation of matter, by positive and negative electrons falling into and annihilating one another, thus setting free the whole of their intrinsic energy as radiation. On this scheme neither energy nor matter had a permanent existence, but only a sort of sum of the two; each was, theoretically at least, convertible into the other. Whether energy is ever transformed into matter we do not know; probably not. But the falling together of electrons and protons forms the obvious mechanism for the transformation of matter into energy, and it now seems practically certain that this is the actual source of the radiation of the stars. A beam of radiation exerts pressure on any surface it falls upon, just as a jet of water does or a blast of air. The reason is that radiation carries mass about with it, and electromagnetic theory tells us the amount of this mass. For example, we can calculate that a searchlight which is radiating 50 horse-power of energy is discharging mass into space with the radiation at the rate of a gramme and a quarter a century; with sufficiently delicate adjustments it might even be possible to observe the recoil of the searchlight. Indeed, the pressure of radiation has actually been measured, although not in this particular way. New mass is of course being continually fed into the searchlight by the electric current.

Each square inch of the sun's surface is in effect a searchlight discharging radiation into space at the rate of 50 horse-power, and so is discharging mass at the rate of a gramme and a quarter a century, and the sun's surface is so large that the sun as a whole is discharging mass into space at the rate of 250 million tons a minute. Now the sun has no source of replenishment. It must have weighed 360,000 million tons more yesterday than to-day, and by to-morrow will weigh 360,000 million tons less. These are not mere speculative statements; they rest on observation, and on generally accepted principles which are directly confirmed by observation.

Allowing for the fact that a more massive star emits more radiation than a less massive one, we can calculate that five or ten million million years ago the sun must have been several times as massive as it is to-day, so that it has already lost most of the mass it had at birth. Of each ton it had at birth only a few hundredweights at most remain to-day. The loss of mass which accompanies radiation is, then, no mere academic hair-

splitting. It is a real astronomical phenomenon, and young stars must be many times as massive as old stars.

There is a certain amount of direct evidence of this change of mass. The radiation of the stars imposes an endlessly recurring capital levy upon their masses, which, as observation shows, is graduated and increases very steeply indeed for the richest stars. The levy makes all the stars poorer, but it also tends to equalize what wealth remains; the older the stars get, the more nearly equal their impoverished masses become. This is a large part of the reason why the stars are nearly equal in mass. The process is most clearly marked in the binary systems, which have been formed by a single star breaking into two. The two component stars of such a system are necessarily of the same age, and it is a matter of observation that the small stars of old systems are nearer to equality of mass than the massive stars of young systems.

Thus observation and theory agree in indicating that the universe is melting away into radiation. Our position is that of polar bears on an iceberg that has broken loose from the icepack surrounding the pole, and is inexorably melting away as the iceberg drifts to warmer latitudes and ultimate extinction.

Five million million years ago the sun had stored up within itself the energy which was destined to provide its light and heat until to-day, and the mass of this energy was many times the present mass of the sun. No means is known by which so much mass could be stored except in the form of electrons and protons. Thus we must suppose that the radiation of the sun through these millions of millions of years has been produced by the annihilation of electrons and protons which existed in it originally, but no longer exist now. These electrons and protons are pure bottled energy; the continuous breakage of these bottles in the sun sets free the radiation which warms and lights our earth, and enough unbroken bottles remain to provide light and heat for millions of millions of years to come.

The amount of energy made available in this way is amazing. The annihilation of a pound of coal a week would produce as much energy as the combustion of the five million tons a week which are mined in the British Isles; an ounce of coal a month would provide locomotive power for all the British railways, while a single drop of oil would take the *Mauretania* across the Atlantic. When we speak of the efficiency of a steam engine as 5 per cent. or so, we regard complete use of the thermal energy of combustion as 100 per cent. efficiency. If we measure the work done against the total intrinsic energy of the fuel, as made available by its complete annihilation, the efficiency is more like 0·00000001 per cent. On this scale the efficiency of the sun and stars is exactly 100·00 per cent.

Modern physical theory shows that the annihilation of an electron must produce a single flash of radiation of wave-length far shorter than any we can produce on earth. As this radiation threads its way through a star, its wave-length is continually increased, or, to use the technical term, the radiation is continually softened. In time it becomes γ-radiation, then hard X-radiation, then soft X-radiation, and finally it emerges from the surface of the star as ordinary light and heat. Consider, however, an electron which is annihilated not inside a star but outside in free space, or in one of the almost transparent nebulae. The short wave-length radiation now undergoes no softening, but travels on until it meets something capable of checking it. Thus all astronomical bodies, including the surface of the earth, ought to be under continual

bombardment by radiation of shorter wave-length, and consequently of greater penetrating powers, than any we can produce on earth.

Many years ago such radiation was detected in the earth's atmosphere by McLennan, Rutherford, and other observers; it has recently been studied in detail by Millikan and others. There is no reason to doubt that it originates just where it ought to, namely, in the great nebulae, and its amount is about what it ought to be, if it is evidence of the whole universe melting away into radiation. The wave-length of the radiation might be expected to reveal the physical process by which it is generated, but the evidence is a bit puzzling. The hardest terrestrial radiation penetrates inches of lead and corresponds to a voltage of hundreds of thousands of volts. The cosmic radiation penetrates about five yards of lead, and the hardest rays are now found to correspond to about 60 million volts. Millikan was at one time inclined to attribute the rays to the combination of four atoms of hydrogen to form an atom of helium, but rays so produced would only be of the hardness corresponding to 30 million volts. There are many ways known to physics of softening radiation, but none of hardening it. Thus we must look for some source more energetic than the synthesis of hydrogen into helium, and I can see no possible stopping-place short of the annihilation of matter. Again, we are not dealing with a minute phenomenon of mere academic interest. In a sense this radiation is the most fundamental physical phenomenon of the whole universe, most regions of space containing more of it than of visible light or heat. Our bodies are traversed by it night and day. Short of going down into a mine or in a submarine we can not escape it, and it is so intense that it breaks up several million atoms in each of our bodies every second. It may be essential to life or it may be killing us.

The Lives of the Stars

The stars are almost certainly born in nebulae of the type of the great extra-galactic nebulae. These nebulae show a great variety of shapes, but a single thread connects them all; they are the shapes of huge masses of gas endowed with different amounts of rotation. So definitely is this the case that when Hubble recently tried to classify the shapes of these nebulae, deliberately and avowedly shutting his eyes to all theoretical considerations, he found that purely observational considerations compelled him to classify them in precisely the sequence I had predicted on theoretical grounds some ten years earlier.

A huge mass of gas which was entirely devoid of rotation would of course assume a strictly spherical shape; rotation would flatten this shape out, just as the earth is flattened by its rotation, until ultimately most of the matter was spread out in a thin disc. Now mathematical theory shows that the thin disc-like structure could not remain a mere featureless mass of gas. Just as the cooling of a cloud of steam causes it to condense into drops of water, so the cooling of a cloud of gas causes it to condense into detached masses. We see the phenomenon in progress in nebular photographs; it is a necessary theoretical consequence of the laws of gases and the law of gravitation.

Now the same theory which predicts that the phenomenon must happen, predicts the scale on which it will happen. We can calculate how much matter will go to the formation of each "drop," and the calculated masses of the drops come out to be just about the same as the masses of the stars. Indeed these drops are stars, and the process just described is that of the birth of stars. Unmistakable stars have been observed in the

outer regions of many of the spiral nebulae. It is naturally not possible to identify every observed spot of light with a star, but some of them show precisely the same peculiar fluctuations of light as characterize a certain class of variable star, the Cepheid variables already mentioned, and these put the identity of these particular spots of light beyond all reasonable doubt.

In these nebulæ, then, we are watching the birth of stars, the transformation of an inchoate mass of gas into an "island universe" of stars. Indeed Hubble found it necessary to end up his classification of nebulae with clouds of stars. At one end of his continuous sequence is a nebula, shaped like a mass of rotating gas, in which not a single star is visible: at the other end a star-cloud in which nothing but stars are visible. Our galactic system of stars is probably the final product of just such a transformation, the Milky Way still recording the position of the equatorial plane of the original nebula.

Stars born in this way may meet with a variety of accidents and these result in different observed astronomical formations. A star may rotate too fast for safety, just as a flywheel may; when this happens it breaks into two, and the two stars so formed revolve endlessly about one another as a binary system. Two stars may run into one another, although this is very rare. A more common occurrence is for two stars to escape running into one another by a narrow shave. When this happens, huge tides are raised on the two stars involved, and these may take the form of long streamers of gas, which ultimately condense into "drops" just as did the gas in the outlying regions of the spiral nebulæ. It seems reasonably certain that the planets were formed in this way.

The birth of the solar system, then, resulted from the close approach of two stars; if a second star had not happened to come close to our sun, there would have been no solar system. It may be thought that with a life of millions of millions of years behind it, one star or another would have been certain to come near enough at some time to tear planets out of the body of our sun. Calculation shows the reverse; even after their long lives of millions of millions of years, only about one star in 100,000 can be surrounded by planets born in this way. A quite unusual accident is necessary to produce planets, and our sun with its family of attendant planets is rather of the nature of an astronomical freak.

In the thousand million stars surrounding our sun there are, at a moderate computation, not more than ten thousand planetary systems, because there has not been time for more than this number to be born. They are of course still coming into existence; calculation suggests a birth-rate of about one per thousand million years. Thus we should have to visit thousands of millions of stars before finding a planetary system of as recent creation as our own, and we should have to visit millions of millions of stars before finding a planet on which civilization, and interest in the outer universe, were as recent a growth as are our own. We are standing at the first flush of the dawn of civilization, and are terribly inexperienced beings.

It may be suggested that the creation of planetary systems is also only beginning, and that in time every star will be surrounded, like our sun, by a family of planets. But no; the stars will have dissolved into radiation or disappeared into darkness before there is time for this to happen. So far as we can judge, our part of the universe has lived the more eventful part of its life already; what we are witnessing is less the rising of the curtain before the play than the burning out of candle-ends on an empty stage on which the drama is already

over. There is not time for many more planets to be born.

Life and the Universe

The planets are the only places we know where life can exist. The stars are too hot; even their atoms are broken up by the intense heat. Nebulæ are in every way unsuitable; even if cool solid bodies exist in them, they would probably be so drenched with highly penetrating radiation as to render life impossible. Life demands a special type of matter, such as does not produce intense light and heat by transforming itself into radiation. We find it only in the surfaces of the stars, which are too hot for life, and in the planets which have been pulled out of these surfaces.

On any scheme of cosmogony, life must be limited to an exceedingly small corner of the universe. To our baby's wonderings whether other cradles and other babies exist, the answer appears to be that there can at best be very few cradles, and there is no conceivable means of knowing whether they are tenanted by babies or not. We look out and see a universe consisting primarily of matter which is transforming itself into radiation, and producing so much heat, light, and highly penetrating radiation as to make life impossible. In rare instances, special accidents may produce bodies such as our earth, formed of a special cool ash which no longer produces radiation, and here life may be possible. But it does not at present look as though Nature had designed the universe primarily for life; the normal star and the normal nebula have nothing to do with life except making it impossible. Life is the end of a chain of by-products; it seems to be the accident, and torrential deluges of life-destroying radiation the essential.

There is a temptation to base wide-reaching inferences on the fact that the universe as a whole is apparently antagonistic to life. Other quite different inferences might be based on the fact of our earth being singularly well-adapted to life. We shall, I think, do well to avoid both. Each oak in a forest produces many thousands of acorns, of which only one succeeds in germinating and becoming an oak. The successful acorn, contemplating myriads of acorns lying crushed, rotten, or dead on the ground, might argue that the forest must be inimical to the growth of oaks, or might reason that nothing but the intervention of a special providence could account for its own success in the face of so many failures. We must beware of both types of hasty inference.

In any case, our three-days-old infant can not be very confident of any interpretation it puts on a universe which it only discovered a minute or two ago. We have said it has seventy years of life before it, but in truth its expectation of life would seem to be nearer to 70,000 years. It may be puzzled, distressed, and often irritated at the apparent meaninglessness and incomprehensibility of the world to which it has suddenly wakened up. But it is still very young; it might travel half the world over before finding another baby as young and inexperienced as itself. It has before it time enough and to spare in which it may understand everything. Sooner or later the pieces of the puzzle must begin to fit together, although it may reasonably be doubted whether the whole picture can ever be comprehensible to one small, and apparently quite insignificant, part of the picture. And ever the old question obtrudes itself as to whether the infant has any means of knowing that it is not dreaming all the time. The picture it sees may be merely a creation of its own mind, in which nothing really exists except itself; the universe which we study with such care may be a dream, and we brain-cells in the mind of the dreamer.

ACTIVITIES IN PLANT PHYSIOLOGY

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Possible activities in plant physiology may be discussed most profitably upon the basis of comprehension of recent movements and present activities in plant dynamics. To gain a perspective of the field it will not be necessary to review the entire subject. The main trend and the direction of the most important developments may be projected or outlined by recalling some of the phases of the subject in which advance has been notable. To do this adequately we need not go farther back than the beginning of the century. Progress in nearly all the branches of science and in invention in the intervening period has been more rapid than in any similar length of time in history.

Researches in biological phenomena characteristic of plants have maintained the general pace. It was at the beginning of this period that DeVries, whose earliest researches date back a quarter of a century previously, made his experimental studies in heredity. That he should have formulated the mutation theory of evolutionary derivation of species by discontinuous variations, the essential feature of which is that of separable, measurable characters, seems to be a logical step from his earlier contribution to the subject of electrolytic dissociation of salts in solutions. DeVries made the mechanism of heredity the subject of experiment to supplement or replace observations on the face of nature; quantitative were substituted for qualitative methods, and the viewpoint taken was physiological rather than anatomical.

So great has been the growth of knowledge in genetics, so numerous its students and so direct its applications in human affairs and in plant and animal industries that it has become a separate academic subject. It is obvious that the original movement has now merged into a stage of diffuse elaboration of details, from which it may emerge only upon the origination of new major conceptions. The perfection of the conception of the gene—its behavior in pure and mixed lines of descent, linkages, crossing over, etc., together—may be taken as in the second stage of movement in this field.

It is now quite on the cards that something definite may result from experimental studies in controlled modifications in heredity. Here I am disposed to believe that my own results from qualitative disturbances obtained by introduction of solutions of electrolytes into ovaries of seed-plants in 1905 constitute the first definite effort in this direction. Tested and pure lines of plants were not available as experimental material nor was it possible at that time to formulate the theoretical conceptions upon which profitable advance might be made in modifying heredity. The recent employment of radiant energy by several skilled investigators has secured results which may form the basis of some positive contributions of great import. It is not yet certain that the genes are affected in such experimentation. In any case it may be safely said that the alterations are to be attributed to destruction of material or to disturbances or rearrangement of the chromosomal mechanism. Whether or not actual constructive action in build-

ing up new characters has been accomplished is yet to be determined.

Other phases of physiology and the contributing workers have been taken over directly by the departments of agricultural or horticultural experiment stations or schools to gain a more speedy and direct application of physiological methods with a consequent loss of contributory power to the general subject. Highly specific results rather than general principles are required.

Contributions in plant physiology find their way into print in a wider variety of journals than any other known subject. Pertinent papers appear in journals of chemistry, biochemistry, physical chemistry, physics, colloids, general physiology, plant physiology, genetics, ecology and in a wide variety of publications of botanical, agricultural, horticultural and forestry science, as well as in the proceedings of societies, academies and institutes. I am unable to name any other field in which the energies of the personnel have been so widely and variously dissipated.

Closely correlated branches are scattered about in a highly inefficient manner in schools, colleges and experiment stations. By reason of this diffusion and dispersion plant physiology in its entirety, including the construction of living matter, and the photosynthetic processes to which the organic world owes its existence, the admitted basis of all agriculture and including within its field the source of nearly all power available to the use of man, is represented by but few more chairs and instructorships in colleges than in 1910. This last count is of little moment, but the deplorable fact remains that the study of plant dynamics as now followed and practiced is clumsy, inefficient and one by which the field of effort tends to become sterilized.

That the content of the subject and that modes of approach have altered at a rapid rate is well illustrated by the fact that a text-book of mine reasonably up to date when published in 1902 is now hopelessly beyond revision as to text and the very table of "constants" would require serious alteration to conform to present-day knowledge. The atom of to-day is not that of 1900 and it is equally certain that the current model will be demoded long before the end of the second quarter of the century.

The content and standards of measurement of such terms as osmosis, plasmolysis, permeability, temperature-effects, growth, tropisms, etc., have changed radically within the laboratory experience of many living workers.

The earlier conception of protoplasm as a foam with solid inclusions was displaced by the idea that it was a two-phase colloid or emulsoid, which idea in turn has given way to the better grounded knowledge that living matter in its more solid portions is a reversible gel with the molecular aggregates arranged in a minute meshwork or fibrillar structure with many free poles. The spaces are filled with watery liquid carrying ions, large or small. The degree of hydration of the jelly depends upon the number of molecules of water held by the free poles of the molecules and by the freely moving ions. Extreme hydration may result in the liquefaction of the jelly and the free movement of particles or aggregates of various sizes in a watery solution as the continuous medium. In some regions of the plant cell, particularly the external part of the plasmatic mass, compounds of the fatty acids, some soluble in water or hydratable and others soluble only in oils, the phospholipins, galactolipins and sterols are present in an irregular layer with strands extending through walls and into the plasma. The arrangement here is one of minute globules with protective layers of proteins, or of phospholipins suspended in a continuous watery medium.

Various combinations are known to exist between carbohydrates and lipoids and between lipoids and proteins.

However complex the system may be, and the above facts simply suggest some of its features, the main feature of protoplasmic material in which the biologist is perennially interested is its hydration. The number of molecules in the shell of water held by the charged particle is in the end the measure of its capacity for action. A whole constellation of agencies affect this feature of living matter. The state of hydration of any plasmatic mass changes unceasingly by the action of the ions or charged particles moving within or through it, and of these the hydrogen ion being the most mobile is the most influential. It is not alone, however, in affecting the colloidal meshwork or the state of suspensions.

We have moved rapidly from the resolution of the minute structure of protoplasm considered as a foam by the use of objective lenses which find their limit at half a sodium wavelength to the employment of the ultramicroscope by which size and movement of particles beyond the range of vision are registered. Cytology must now, to make further gains in its salient, move over onto a basis of the dynamics of colloids. Living matter is like a stream. Depth or cross-section of the bed are features of minor interest unless correlated with the speed of the current, nature and movement of the silt carried, erosive action, source and destination of flow.

Nothing in the foregoing is to be taken as belittling the importance of architecture or the arrangement of the component parts of the cell. On the contrary, there has never been a time when the plan of construction of the living machine has assumed such importance. Throughout the entire range of metabolic activity, in all transformations of energy, in all phenomena depending upon viscosity and surface energy, in all movements of material into and out of the cell, growth, and in operations so wide and large as the movement of water in cohesive columns in stems hundreds of feet in length the state of the colloidal particles, relative positions, form and structure of the walls, and the mechanisms formed by the tissues are of the first importance. Physiological anatomy in its ultimate sense has come into its own.

No matter what field of physiology is considered the experimenter, to attain results of any real value, must proceed upon the basis of the constitution of living material. The conception of a protoplast as a blob of protein no longer suffices to explain cell-activities. The liquid and gelatinous mass also includes mucilages and lipoids. The reactions of the living cell are a resultant of the conjoint action of its constituents, particularly as to exchanges of material with the environment, in which case the composition and condition of the cell-wall is also to be taken into account.

After participating in the work of the Desert Laboratory for more than two decades I wish to restate the conviction that nearly all the more important problems of plant physiology concern the relations of living matter to water in some manner.

The action of the chlorophyll-mills in the conversion of radiant energy and the reduction processes for which they furnish the scene and the accessory materials might well be designated as the most fundamental concrete chain of processes with which biological science has to deal. The approximation of the set of reactions in the green cell, and arrangements by which light acting upon preparations in glass or quartz containers may induce the formation of other substances which may be utilized by living cells carry a series of problems

well worth any expenditure or attention that can be given to them. Encouraging advances have been made in both phases of the subject within the last few years.

It might be profitable to venture a few steps further to point out changing viewpoints as to the nature of stimulations and responses as to the intervention of catalysts in tropistic reactions and the employment of the conception of hormones or messengers transmitting reactions or "trigger effects" to distant cell-masses through living cells, along water-filled conduits and even through sections of dead organs.

We were perforce content until recently to regard growth as one of the unexplained and unexplainable "vital phenomena." Effort is now being made to give mathematical expression of its rate and course. The value of the derived formulae will increase with the inclusion of more of the main variables in the calculations. Like all external manifestations the underlying processes are complicated. If increases in volume are conditional on the formation of a building material as inherent in many theories, and upon substances increasing extensibility of cell walls, actual increases of the molecular mesh of living matter and of the surface attraction of charged particles in osmosis and swelling are also to be taken into account.

Time does not allow a discussion of other important aspects of the subject. I have simply chosen activities in fields with which I have some acquaintance for the purpose of establishing a perspective. I wish further to emphasize the fact that the ends of physiology are not to be attained by restricted methods, standardized equipment or limited range of experimental material. Living material of all types, dead cell-masses, extracted constituents, physical models, such as those with which Pfeffer began his epoch-making researches in osmosis, jellies illustrating some of the properties of living matter, and instruments adapted to the registration of the widest range of behavior and physical properties of protoplasm and of other colloids are all material and tools useful in the workshop of the physiologist.

Specific researches, institutional arrangements and instructional schemes must always be dealt with by those most concerned. But in all activities in the domain of plant physiology, whether research in remeasuring or testing previously accepted generalizations, development of new methods for exploring unknown fields, or in the most specific application of new or little known principles to the nutrition, growth and productivity of crop plants, the soundest and best results will be those attained by the continued use and application of the facts and theoretical conceptions of the mechanism of living matter, as determined chiefly by a study of the dynamics of its colloids, and by increasingly adequate and accurate methods of measurement of impinging forces or environmental agencies.

The art of agriculture, inclusive of breeding, fighting diseases of crop plants, increasing yields of grain and fruits, altering qualities of products, selection and domestication of wild plants, will advance at a rate dependent upon the manner in which practice is continually modified to conform to the latest findings in technical research. Such an adjustment is so well illustrated in medicine, metallurgy and many other fields that it seems unnecessary to discuss the indecision as to this matter which may be encountered in many institutions devoted to industries based on the findings of plant physiology.

WARD'S NATURAL SCIENCE ESTABLISHMENT

By HERMAN L. FAIRCHILD
EMERITUS PROFESSOR, UNIVERSITY OF ROCHESTER

THE passing of this unique institution to the ownership of the University of Rochester is an incident of scientific and educational interest. But the transfer of the quasi-commercial institution to one that is wholly educational is not as surprising and strange as it may appear. The establishment began when its founder, Henry A. Ward, was the professor of natural science in the college; and it was housed on the college campus. Moreover, the enterprise was connected with, or an outgrowth of, the Ward Collections which had been presented to the university. In 1869, after the burning of its building, the establishment was relocated directly across the narrow street (College Avenue), where it has remained.

For over sixty years "Ward's" has been the emporium for natural history material, and with no rival in the wide field. Any fair account of the institution must be a part of the life story of Henry A. Ward, a most remarkable man, "the king of museum builders." The full account of his restless life has not been written. His singular modesty delayed the dictation of his memoirs, and his death by accident, in 1906, destroyed the hope. He was a charming writer and a peerless raconteur. His self-told narrative would have made the most interesting travel-book ever written.

Two racy articles about Ward have been written by William T. Hornaday; one in the *Commercial Travellers Home Magazine*, February, 1896, ten years previous to Ward's death; the other in *The Nation*, July 12, 1906. These have special value because Hornaday is one of the eminent scientific men who had "graduated" from the establishment. The quotations in this writing are from those articles.

As a very young man Ward was a student at Williams College, leaving there to join Agassiz at Cambridge; but doing his geologic work in the Ecole des Mines, in Paris. While collecting and selling fossils in France, England and Germany to pay his expenses in the School of Mines he conceived the plan of making a great and comprehensive educational collection in geologic science. After he had secured examples of the limited material then available in America he spent six years wandering over Europe and part of the orient, quarrying, exchanging and purchasing material.

In the year 1861 his collections in phenomenal geology, paleontology, petrology and mineralogy were exhibited in a large hall in Rochester, to the delight and wonderment of all visitors. Letters from several of the most eminent naturalists of that day assert that the collection as a whole was the finest of its kind in America. And Ward was then only twenty-seven years of age.

But the collection was not salable. It was too large and complete. No institution in America then desired such a great geologic museum. To purchase the material and repay his uncle, Levi Ward, who had financed him, the friends of Ward and the university raised a fund of $20,000 and gave the collections to the college. Its display used the entire top floor of Anderson Hall. A large proportion of the 40,000 labels are in the hand-printing of G. K. Gilbert, who was the senior "alumnus" of Ward's Establishment.

FIG. 1. A GROUP OF WARD'S TAXIDERMISTS, IN 1872. THE BOY IS HENRY L. WARD, AND THE MAN WITH SMOOTH FACE IS FREDERIC A. LUCAS

Twenty years later the museum was removed to Sibley Hall and left unarranged. One of the conditions which drew the writer to Rochester, in 1888, was the opportunity of reclassifying and installing the superb collections.

During Ward's activity in Europe he was able to obtain permission to make plaster molds of the very striking and unique fossils in the great royal museums, which he reproduced for his Rochester museum, Of these Hornaday says: "No sooner were these wonderful casts brought forward than other institutions of learning sought copies from the same molds, and 'Ward's Casts of Celebrated Fossils' was the final result. American teachers and students, to whom the originals were inaccessible, were delighted with them. Illustrated catalogues were issued, the largest of which we used in my alma mater as a text-book."

"Professor Ward's most notable achievement as a scientist and educator was, in my estimation, the colossal task which culminated in the . . . Collection of Casts. . . . Poor indeed is the college or university which does not contain a series. . . . About two hundred sets of them have, I think, found lodgment in the museums and higher institutions of learning in this country."

With accumulation of paleontologic material the plaster imitations are, naturally, in disfavor. But sixty years ago they were a necessary and admirable means of illustration. Even to-day they are desirable for certain unique fossils, like the *Archeopteryx*. And the cast of

a fine fossil is often better than a poor or imperfect original.

Many of the Ward publications, which now number two hundred and ninety-five circulars and forty-three catalogues, have been in demand for use with college classes, especially the ones relating to zoology and paleontology.

Supplying models of type fossils (originals of the invertebrates being largely in the Rochester Museum) was the larger part of the initial work of the establishment. But the business rapidly expanded until it covered all classes of museum and laboratory material in geology and zoology, including taxidermy. Of the latter Hornaday writes: "As early as 1873, when the best of our scientific museums were in their swaddling clothes, and skilled museum preparators were a negligible quantity, Professor Ward assembled at Rochester a corps of the best French, German and American taxidermists, molders and modelers that high wages could procure. In 1876 I was astonished in finding that Rochester afforded better facilities for the study of museum making than Paris, London or Berlin.

"Scores of other men have been trained here in various branches of scientific work and have gone forth to fill positions of responsibility. The Society of American Taxidermists was founded here in 1880 by Professor Ward's taxidermists, and in all its work always received from him hearty sympathy as well as active support and cooperation. It is my firm conviction that no man living has done as much toward

FIG. 2. THE STUFFED SKIN OF JUMBO. AT RIGHT ARE THE TWO YOUNG MEN WHO MOUNTED IT, CARL AKELEY AND WILLIAM T. CRITCHLEY. THE MOUNT IS AT TUFTS COLLEGE; PRESENTED BY P. T. BARNUM. THE SKELETON IS IN THE AMERICAN MUSEUM OF NATURAL HISTORY

the promotion of the art of taxidermy as has been done by Henry A. Ward and the influence created by him."

The photograph, figure 1, is a relic of the early days, taken in 1872. It would be interesting to know where that rhino is to-day.

Carl Akeley went to Ward's in 1883, remaining four years, and associated with William Critchley and William M. Wheeler began his brilliant work. (See the March–April issue of *Natural History*, especially pages 133–146; also Akeley's "In Brightest Africa.")

Ward's was a training school for naturalists. Besides his two sons, Charles H. Ward and Henry L. Ward the following men are counted as among the "alumni." G. K. Gilbert, Frederic A. Lucas, William T. Hornaday, William M. Wheeler, Carl Akeley, Walter B. Barrows, E. W. Staebner, Edwin E. Howell, Charles H. Townsend, George H. Chadwick, Frank C. Baker, and many others.

Ward's establishment was never conducted on a purely commercial basis. "With him (Ward) the idea of educating the masses in the natural sciences by means of object lessons became an absorbing passion. He cared for money only to spend it in wider travel and more collections. And while he found purchasers for great collections as no other man ever did, the huge checks which he received he always joyfully scattered to the ends of the earth in the purchase of more 'museum material.' "

Ward's passion for collecting often overstocked the institution and "broke the market." But serious financial troubles never greatly interfered with the activities of the establishment.

For some years before 1892 the geologic branch of the business was in the name of Ward & Howell; the latter being Edwin E. Howell, who left to found the "Microcosm" in Washington city, devoted chiefly to construction of relief maps.

Professor Ward renewed his world-travel during the later years of his life in carrying out another ambition, to make the most complete collection of meteorites in the world. This is now owned by the Field Columbian Museum, which gave for it over $100,000.

As Professor Ward gradually relinquished control of the establishment it was taken over by his cousin, Frank A. Ward, and his two sons, Hawley Ward and G. Merrit Ward. The sons have now generously donated the institution, its stock, business and good-will, to the University of Rochester in memory of their father.

The new relationship of "Ward's" will be an interesting experiment. It is an example of the widening trend in educational work. The university also possesses the beautiful Eastman Theater, in connection with the Eastman School of Music.

The Wards will continue in the management of the establishment for a few years, while its future operation is being determined. Evidence of its vitality is seen in the recent departure of its consulting mineralogist, George H. English, on a year's trip around the world in search of more material.

THEODORE WILLIAM RICHARDS

THE PROGRESS OF SCIENCE

THEODORE WILLIAM RICHARDS

In the untimely death of Professor Richards, at the age of sixty years, America loses its most distinguished chemist. His father was a leading painter, whose daughter followed the same career. The younger son, Herbert Maule Richards, who died a few weeks ago, was for twenty-five years professor in Barnard College, Columbia University, and contributed largely to the modern development of physiological botany. We have thus a notable example of family distinction and of the relation that exists between science and the fine arts.

It may be that this journal will be able to print an adequate appreciation of the great contributions to chemistry made by Professor Richards during his tenure of the professorship at Harvard and the directorship of the Wolcott Gibbs Memorial Laboratory. In the meanwhile two tributes may be quoted from the daily press which are of interest in indicating on the one hand the high regard in which Professor Richards is held and on the other the intelligent attention now given to science by the general public.

The New York *Times* says in an editorial article:

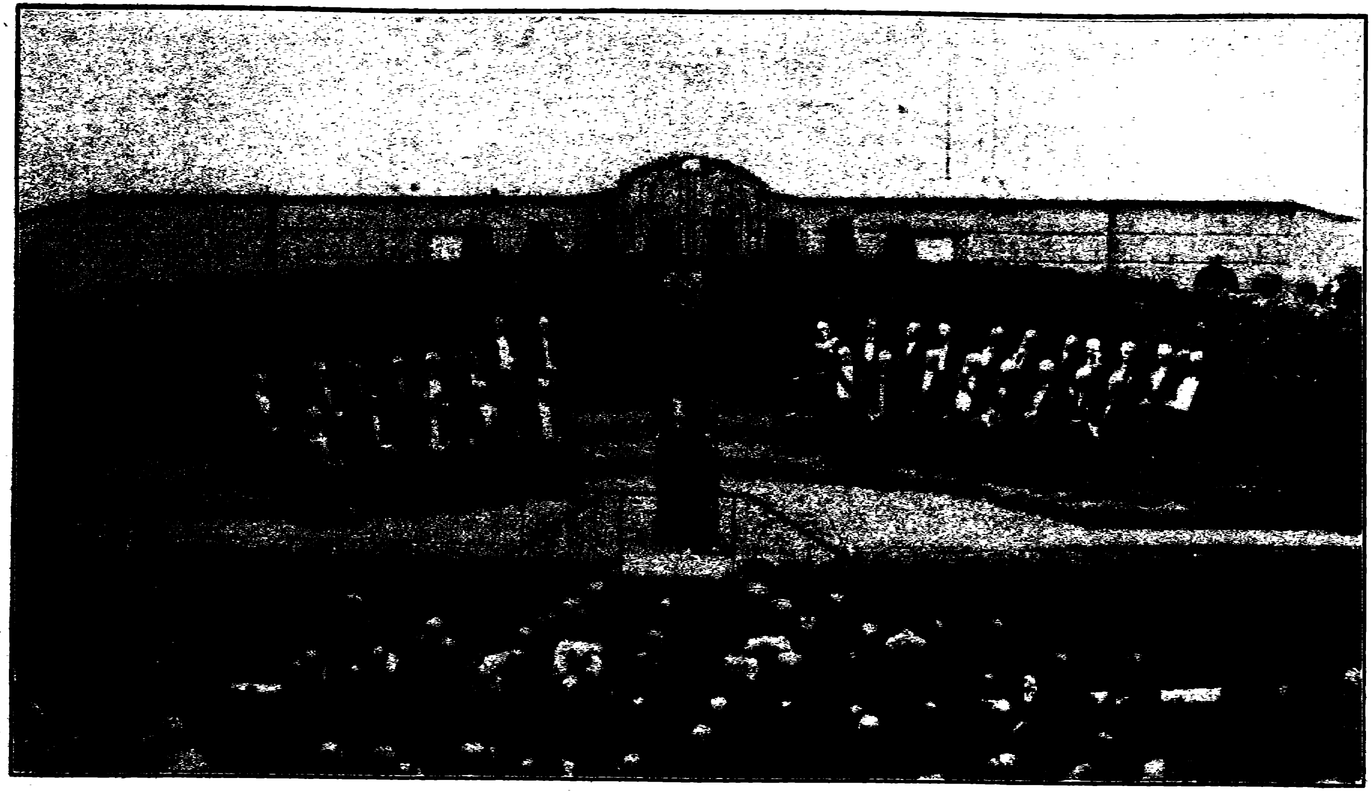
If Lord Kelvin's oft-quoted dictum "Science is measurement" needed any justification, it would be found in the career of Professor Theodore W. Richards, of Harvard; for with him passed one who was a distinguished scientist because he was a skillful, patient and accurate measurer. There is nothing spectacular about determining atomic weights, and Professor Richards played no vivid part in the popular scientific news of the day. Yet his table of atomic weights, which represents the labor of thirty years and constitutes the very basis of chemistry, won for him the Nobel prize in 1914.

Atoms have weight. Lead weighs more than 200 times as much as hydrogen, for example. That fact was ascertained not by weighing an atom all by itself, but by determining the proportions in which atoms combine. Countless such determinations had convinced chemists not only that the atom is indestructible and indivisible but that its weight is constant. Slight irregularities were attributed to errors in experimenting. Richards's restless, inquiring mind was not satisfied. He made careful measurements with copper, silver, sodium. Whether the element came from Alaska or China the result was always the same. Then came the discovery of radioactivity. There was reason to believe that the end products of the spontaneous decomposition of uranium and thorium must be similar to lead if not identical with it. Richards was the very man to settle the question. He made as many as 1,000 fractional distillations of Australian lead nitrate, believed to contain both ordinary and uranium-radium lead. In the end he startled chemists with the announcement that there are at least two kinds of lead (now there are four and possibly six), and that there is a difference between the lead with which we are familiar and that obtained from radioactive ores. Were these different varieties lead elements in the old sense? Hardly. Soddy found it necessary to coin the now generally accepted designation "isotopes." Since then Aston, another Englishman who has built on Richards's work, has received the Nobel prize for his study of isotopes, and the question has been raised whether or not all the elements with which we are familiar may not have broken down from heavier and more complicated structures. So it happens that the influence of Richards is felt throughout the whole field of physical chemistry and that it is scarcely possible to read a technical interpretation of the stars or the transmutation of matter without finding an argument buttressed by a reference to his determinations of atomic weights.

The editor of the New York *Herald-Tribune* writes:

The death of Theodore Richards removes a great figure of American chemistry, perhaps the greatest. It completes, also, a misfortune to science the first half of which happened only a few weeks ago when Professor Herbert Maule Richards, of Barnard College, a brother three years the junior of Theodore, was taken by death. It is seldom given to two brothers to attain such equal eminence both in their chosen sciences and in the affections of their colleagues as was granted to this unusual pair.

When Theodore Richards died this week American science and the faculty of Harvard lost the most intimate friend of the chemical



THE CEREMONY OF CONFERRING THE NOBEL PRIZES

SCENE IN THE CONCERT HALL AT STOCKHOLM LAST DECEMBER ON THE OCCASION OF THE CONFERRING OF THE NOBEL PRIZES BY KING GUSTAV. THE RECIPIENTS SEATED IN THE FRONT ROW ON THE LEFT SIDE OF THE PLATFORM ARE PROFESSOR J. WAGNER TAUREGG, OF VIENNA, AND PROFESSOR J. FIBIGER, OF COPENHAGEN, TO WHOM THE PRIZES IN MEDICINE FOR THE TWO PAST YEARS WERE GIVEN; PROFESSOR C. T. R. WILSON, OF THE UNIVERSITY OF CAMBRIDGE, AND PROFESSOR A. H. COMPTON, OF THE UNIVERSITY OF CHICAGO, BETWEEN WHOM THE PRIZE IN PHYSICS FOR 1927 WAS DIVIDED, AND SIGNORA GRAZIA DELEDDA, OF ITALY, WHO RECEIVED THE PRIZE IN LITERATURE

atom in the world; a chemist almost unique in his generation for sympathetic understanding of the physicist's views of atoms, as brilliantly exemplified in recent years by the theories of Bohr and the experiments of Thomson, Rutherford and Millikan. An atom has no property more fundamental than its atomic weight and no man in the history of science did more than Theodore Richards to define these weights and to make them certain.

To Herbert Richards the study of living matter proved more attractive than that of atoms. Prominent in that small group of American pioneers who established thirty years ago the new science of the physiology of plants, Herbert Richards brought to his specialty an experimental skill, a sound knowledge and a fine common sense which had won for him when he died unquestioned authority concerning the gases that living plants breathe in and out. His was an authority seldom exercised of his own will, for he was the most modest of men; but upon it his colleagues counted with assurance and delight and they were dismayed to lose it. His lovable personal qualities his friends will long remember with the distress of irreparable loss.

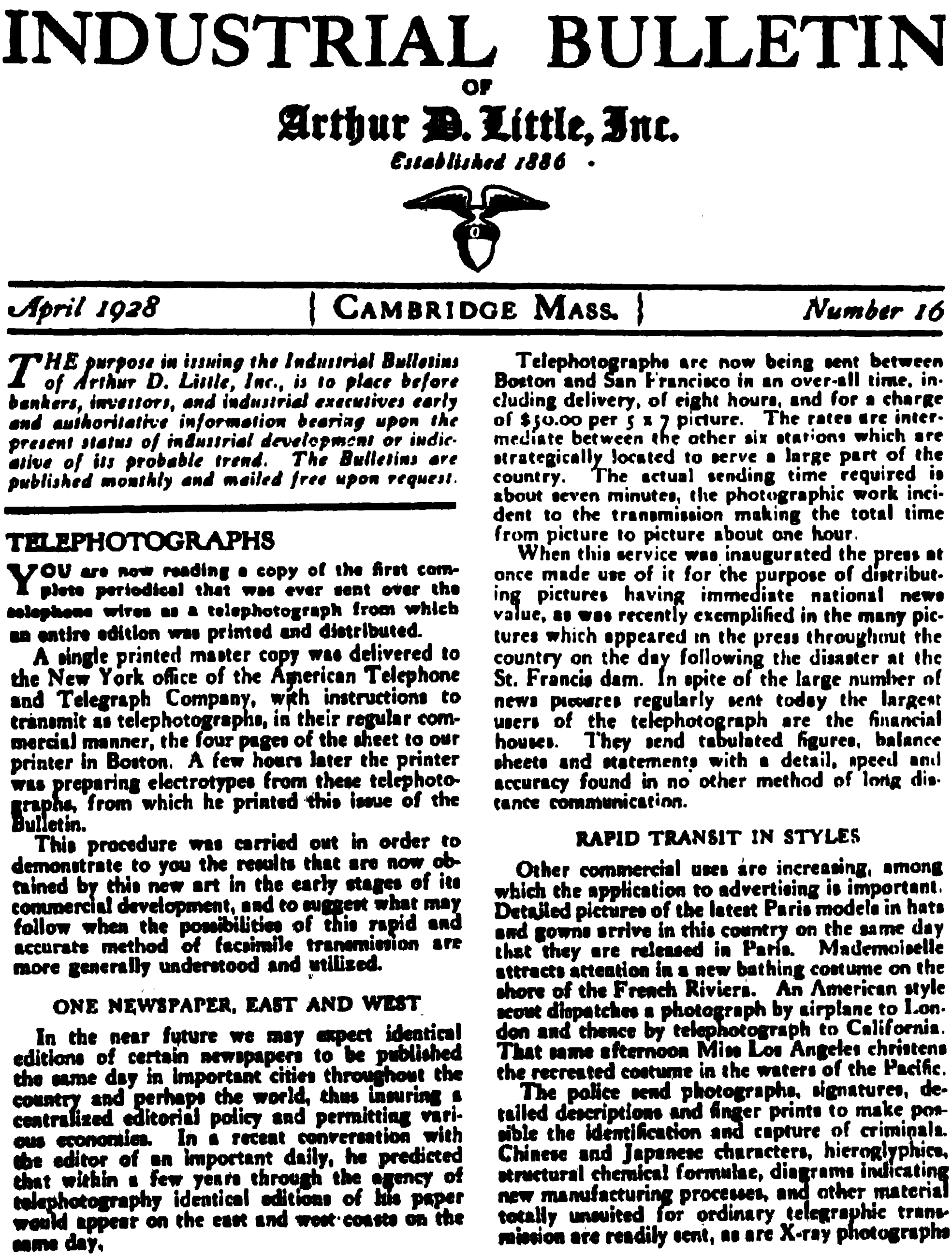
The Richards brothers make an interesting study in heredity. Sons of a father who was the foremost marine painter of his time and a mother distinguished in literature, their ancestry seemed to hold little promise of the cold-blooded exactness which is an essential part of science. It was more imaginative than critical, yet both brothers lived to rank among the sanest and severest critics in their respective fields. The truth is that the imaginative strain is far from negligible in the scientist, for, as Herbert Richards used to declare, insight and foresight are the experimenter's greatest aids. Certainly it was no slavish imitation of his predecessors which led Theodore to conclude before any one else that the heart of an atom lies close to its atomic weight. William T. Richards, the painter father, bequeathed much to the world, for bits of beauty that he conceived still honor the walls of many galleries. But nothing of his was greater, perhaps, than that spark of imagination which did such service for science in the persons of his two sons.

ELECTRONS AND WAVE MOTION

The scattering of X-rays by a crystal results in the production of strong scattered beams in certain directions, and this fact has always been explained on the hypothesis that X-rays are an electromagnetic wave disturbance of the same sort as radio waves and visible light. The recent experiments of Dr. C. J. Davisson, reported to the American Physical Society, demonstrate that a beam of electrons shows the same characteristic scattering effects as X-rays. The inference seems to be that there is some sort of a wave-motion associated with the motion of a beam of electrons. A few years ago such a statement would have seemed scarcely credible, but we are now prepared to receive it with less scepticism because of recent work in the quantum theory.

The experiments, which were performed jointly with Dr. L. H. Germer at the Bell Telephone Laboratories, showed that the observed wave-length of the electron beam was exactly that which is predicted by the quantum theory as developed by L. de Broglie, E. Schroedinger and others. This wave-length is numerically equal to Planck's constant of action divided by the momentum of the electron. This means that the electron wave-length decreases with increasing speed. For electrons accelerated by 100 volts, the wave-length is roughly equal to the diameter of a single atom.

In these experiments the source of the electrons was a hot filament just as in ordinary radio thermionic tubes. These were accelerated by a positive grid voltage which could be varied at will. The potential used ranged from about 50 to 375 volts. The beam of electrons impinged on a nickel crystal, and some of them were absorbed in it; others were scattered back from the surface of the crystal. Of those that are scattered back some come back without having lost any speed—they have elastic encounters



INDUSTRIAL BULLETIN

OF

Arthur D. Little, Inc.

Established 1886

April 1928 | CAMBRIDGE MASS. | *Number 16*

THE purpose in issuing the Industrial Bulletins of Arthur D. Little, Inc., is to place before bankers, investors, and industrial executives early and authoritative information bearing upon the present status of industrial development or indicative of its probable trend. The Bulletins are published monthly and mailed free upon request.

TELEPHOTOGRAPHS

YOU are now reading a copy of the first complete periodical that was ever sent over the telephone wires as a telephotograph from which an entire edition was printed and distributed.

A single printed master copy was delivered to the New York office of the American Telephone and Telegraph Company, with instructions to transmit as telephotographs, in their regular commercial manner, the four pages of the sheet to our printer in Boston. A few hours later the printer was preparing electrotypes from these telephotographs, from which he printed this issue of the Bulletin.

This procedure was carried out in order to demonstrate to you the results that are now obtained by this new art in the early stages of its commercial development, and to suggest what may follow when the possibilities of this rapid and accurate method of facsimile transmission are more generally understood and utilized.

ONE NEWSPAPER, EAST AND WEST

In the near future we may expect identical editions of certain newspapers to be published the same day in important cities throughout the country and perhaps the world, thus insuring a centralized editorial policy and permitting various economies. In a recent conversation with the editor of an important daily, he predicted that within a few years through the agency of telephotography identical editions of his paper would appear on the east and west coasts on the same day.

Telephotographs are now being sent between Boston and San Francisco in an over-all time, including delivery, of eight hours, and for a charge of \$50.00 per 5 x 7 picture. The rates are intermediate between the other six stations which are strategically located to serve a large part of the country. The actual sending time required is about seven minutes, the photographic work incident to the transmission making the total time from picture to picture about one hour.

When this service was inaugurated the press at once made use of it for the purpose of distributing pictures having immediate national news value, as was recently exemplified in the many pictures which appeared in the press throughout the country on the day following the disaster at the St. Francis dam. In spite of the large number of news pictures regularly sent today the largest users of the telephotograph are the financial houses. They send tabulated figures, balance sheets and statements with a detail, speed and accuracy found in no other method of long distance communication.

RAPID TRANSIT IN STYLES

Other commercial uses are increasing, among which the application to advertising is important. Detailed pictures of the latest Paris models in hats and gowns arrive in this country on the same day that they are released in Paris. Mademoiselle attracts attention in a new bathing costume on the shore of the French Riviera. An American style scout dispatches a photograph by airplane to London and thence by telephotograph to California. That same afternoon Miss Los Angeles christens the recreated costume in the waters of the Pacific.

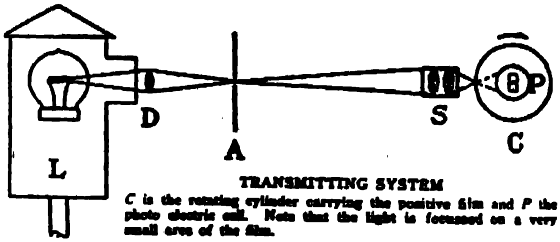
The police send photographs, signatures, detailed descriptions and finger prints to make possible the identification and capture of criminals. Chinese and Japanese characters, hieroglyphics, structural chemical formulae, diagrams indicating new manufacturing processes, and other material totally unsuited for ordinary telegraphic transmission are readily sent, as are X-ray photographs

REPRODUCTION OF A TELEPHOTOGRAPH

THE FIRST TWO PAGES OF THE *Industrial Bulletin* OF ARTHUR D. LITTLE, INC., WHICH WAS TRANSMITTED BY TELEPHOTOGRAPH FROM THE NEW YORK OFFICE OF THE AMERICAN TELEPHONE AND TELEGRAPH COMPANY TO THE PRINTERS IN BOSTON AS DESCRIBED IN THE TEXT. THE WIDTH OF THE PAGE IS REDUCED FROM SEVEN TO FIVE INCHES AND THE TYPOGRAPHY LOSES IN CLEARNESS BY THE REPRODUCTION

which permit a physician at a distance to diagnose an emergency case.

While the value and possibility of telephotography have been recognized for a long time, faithful transmission of a picture has only recently been made possible by combining such new developments as the photoelectric cell, the vacuum tube amplifier, electrical filters and the use of carrier currents. Telephotography is, therefore, not the result of any single invention, but the product of many able minds each working on the perfection of one or more of the several coördinating parts.



TRANSMITTING SYSTEM

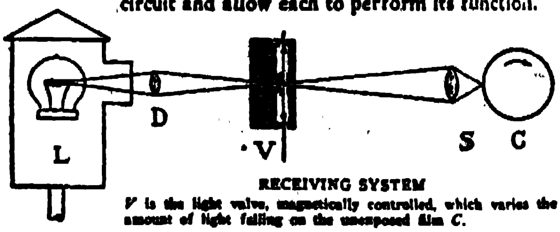
C is the rotating cylinder carrying the positive film and P the photo electric cell. Note that the light is focussed on a very small area of the film.

HOW IT IS DONE

In contrast with the technical difficulties which had to be overcome, the principle involved in telephotography is relatively simple. A 5 x 7 positive of the picture to be transmitted is made on a photographic film. This positive is mounted on a frame in the form of a horizontal cylinder which rotates one and one-half revolutions per second and in each revolution moves along the direction of its axis one one-hundredth of an inch. A light beam is sent through the film onto the photoelectric cell at the center of the cylinder. The greater the intensity of the light falling on this cell the greater the intensity of the current which the cell permits to pass. Thus when solid black appears on the positive film no light falls on the cell and the current flowing through the cell is very small; where the film is transparent more light falls on the cell and the amount of current which it passes is greater and in proportion to the intensity of the light which it receives. Thus in a spiral trace the light beam moves slowly over the entire surface of the film and produces a fluctuating current which varies in intensity with the light and shade of the original picture. This electric current is amplified by means of the familiar vacuum tube amplifiers and passed through the telephone circuits to the various receiving points where it is again amplified, and is made to control a light valve. This is a magnetically operated shutter of great sensitiveness, controlling a beam of light. The beam plays upon a cylinder of the same diameter and revolving at the same speed as the cylinder at the transmitting end. On this cylinder is an unexposed photographic film which becomes the negative from which positive prints are made.

Perhaps a clearer mental picture of the mechanism of transmission will be obtained if the reader will place a ruler across the line of capitals forming the title — INDUSTRIAL BULLETIN. It will be seen that each letter is made up of a series of dashes which in themselves form a broken line across the sheet. On this printed page the result is either black or white, the light valve having been either wide open or shut; on a photograph the intermediate grays would be as accurately shown, the valve being partly open.

There are many technical details of importance that must be incorporated in such a system. It is absolutely essential that the two cylinders start and move in synchronism. Impulse motors maintained at constant speed by means of tuning forks, one of which controls the other, are used for the purpose. The starting signal, the tuning fork control signal and the pulsating current carrying the picture are transmitted on carrier currents of different frequencies, in much the same way that the pulsating current from the microphone is impressed on a carrier current for radio broadcasting. Filters at the receiving end similar to radio tuning coils and condensers separate the different frequencies from the single telephone circuit and allow each to perform its function.



RECEIVING SYSTEM

V is the light valve, magnetically controlled, which varies the amount of light falling on the unexposed film C.

TRANSMISSION REQUIREMENTS EXACTING

Only the very best telephone lines are satisfactory for these exacting requirements. Even the special lines used for radio chain broadcasting are not entirely suitable for telephotography. Occasional distortion during a radio program

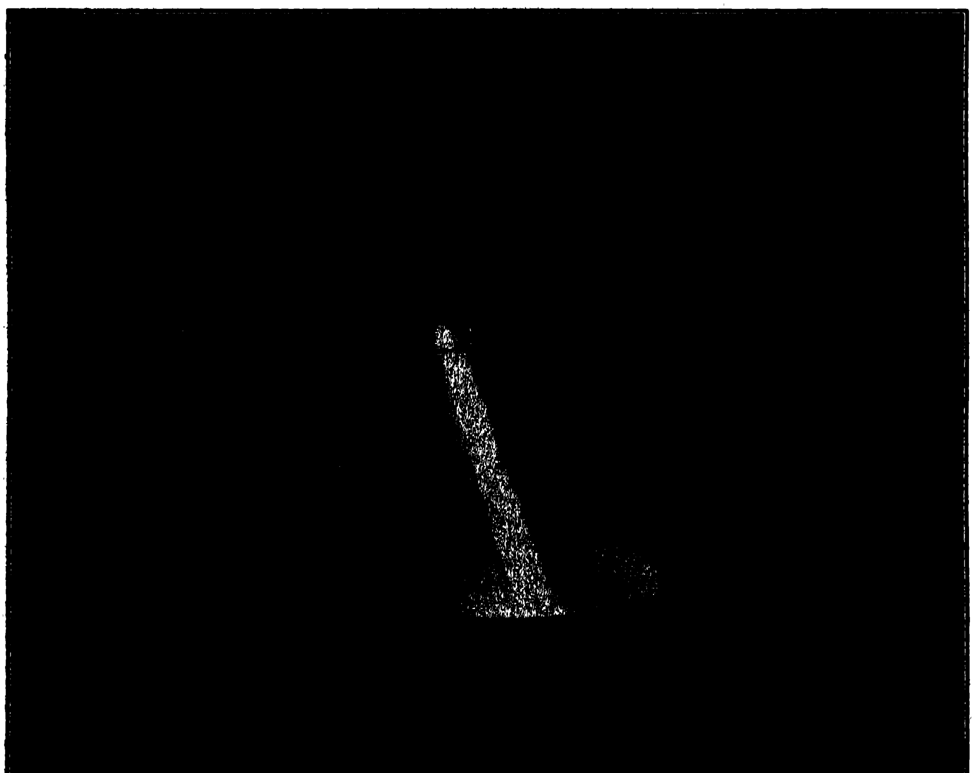
THE CONCLUDING PART OF THE ARTICLE NOT REPRODUCED IN THE PHOTOENGRAVING IS AS FOLLOWS: WOULD NOT GREATLY IMPAIR RECEPTION, BUT A SLIGHT AMOUNT OF DISTORTION DURING THE TRANSMISSION OF A TELEPHOTOGRAPH WOULD RUIN THE PICTURE. WE ANTICIPATE A RAPID GROWTH IN THE USE OF THIS NEW MEANS OF COMMUNICATION, AND BELIEVE THAT MANY EXECUTIVES, BY WHOM THE DEVELOPMENT IS NOW REGARDED AS LITTLE MORE THAN AN INTERESTING EXPERIMENT, WILL SOON BE USING IT REGULARLY IN THE CONDUCT OF THEIR BUSINESS

with the crystal like the impact of a billiard ball on a cushion. A little collecting device was arranged so that it could be moved to various positions in front of the crystal to find how many electrons were scattered in the various directions without loss of speed. The entire arrangement was enclosed in a large glass tube in which was maintained the best vacuum attainable with modern technique.

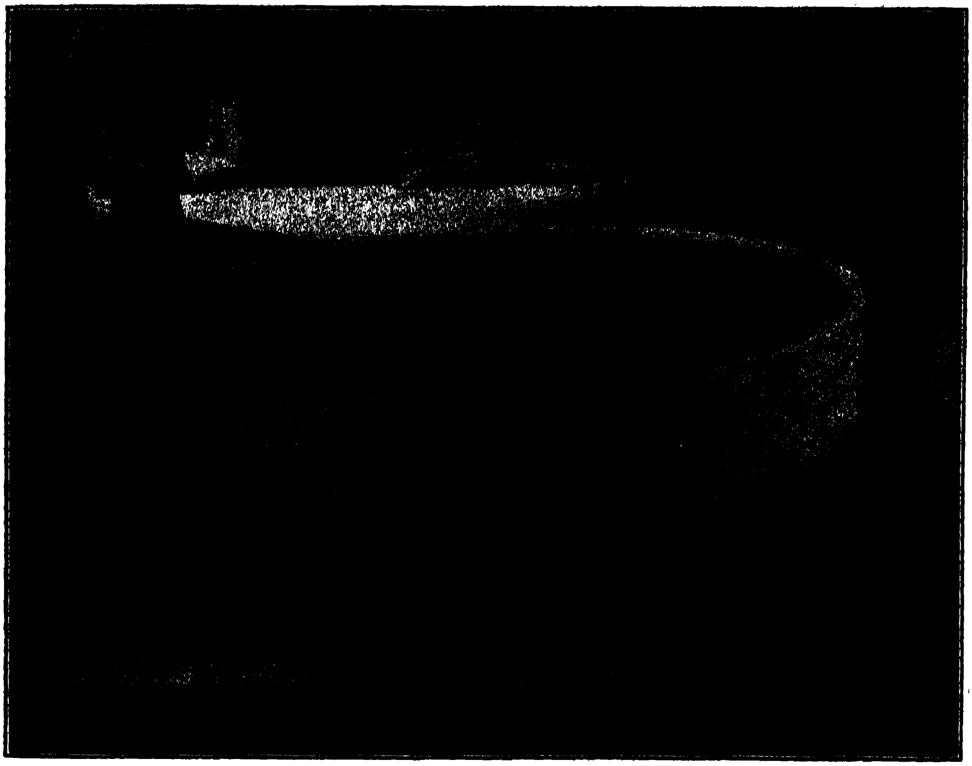
With this arrangement the number of electrons scattered in different directions was found to depend on the direction in the same way as does the scattering of X-rays by a crystal.

According to Dr. Davisson the situation confronting physicists with regard to electrons is now something like the dilemma confronting the theory of light. For many years all the facts concerning light could be explained by assuming it to be simply a wave motion. Then the quantum theory, in the hands of Planck, Einstein and A. H. Compton, showed that radiation had also to be regarded as having something corpuscular about it. Similarly, for many years electrons were believed to be simply corpuscles of negative electricity. But now recent developments in quantum theory, confirmed by these experiments, show that there is something wave-like about them.

The reconciliation of the apparently conflicting wave and corpuscular viewpoints, both in regard to light and in regard to electrons, is one of the most important problems for theoretical physics.



CASTING OF THE OPTICAL DISK



THE OPTICAL DISK

CASTING OF AN OPTICAL GLASS DISK

THE closing act in an interesting scientific drama that has lasted more than eight months has been staged at the Bureau of Standards, Department of Commerce, with the uncovering of the furnace containing a great disk of optical glass, 70 inches in diameter, 11 inches thick and weighing about 3,500 pounds. When the cover was removed in the presence of a small but distinguished group of scientific experts the glass was found to be practically perfect, and the long period of suspense for those responsible for its production was over. The successful consummation of this work has resulted from the cooperative efforts of several men within and outside the bureau, particular credit being due Mr. J. Walter Drake, former assistant secretary of commerce, Dr. S. W. Stratton, president of the Massachusetts Institute of Technology, Professor C. C. Crump, of Ohio Wesleyan University, and Mr. P. H. Bates, Dr. A. Q. Tool and Mr. A. N. Finn, of the Bureau of Standards.

The disk will be used as a great concave mirror for the new reflecting telescope of the Perkins Observatory at Ohio Wesleyan University, Delaware.

The money with which to establish this observatory was left to the university by Professor Hiram Mills Perkins, of Ohio Wesleyan. It was his desire to establish an observatory of the first rank at the university and that the entire equipment be of American manufacture. It is significant that Professor Perkins had no desire for the observatory to bear his name, his sole wish being, as he expressed it, to enable the students of Ohio Wesleyan and men everywhere to "love God and serve Him more acceptably."

Nevertheless, after his death in 1924, his name was given to the new observatory, work on which had already been in progress for two years.

There was only one real obstacle to delay ultimate achievement—large disks of optical glass of the size required had never been made in this country and only twice abroad. Those that have been successfully completed are said to be imperfect, and although imperfections in the glass are not so important in a reflecting telescope as in a refractor, nevertheless it is always desirable to have glass as nearly perfect as possible.

After four unsuccessful attempts to obtain a disk of the size required, a unique method was developed by Mr. A. N. Finn in charge of the Bureau's glass section: 1,000 pounds of cullet (broken glass of the same composition as the glass to be made) and 4,600 pounds of sand and chemicals were melted in a single large pot in a gas-fired furnace. The molten glass was stirred by hand for six hours and at the proper time on May 7, 1927, the pot was tapped. The molten glass was flowed into a mold of the required size which was specially designed for this purpose. This mold was at the same time a carefully insulated annealing furnace, provided with electrical heating elements by means of which the temperature could be adjusted and controlled to within a degree.

The temperature of the glass when poured was about 2,400° F. For one week the temperature was slowly lowered until it reached 1,112° F. The glass was held at this point for about four days to allow the temperature of the glass and furnace to become uniform throughout. At 1,112° F. this particular kind of glass (boro-silicate crown) is quite rigid and yet sufficiently viscous to yield to cooling stresses without danger of cracking.

Beginning on May 18, the glass was allowed to cool slowly at an average rate of 4½° F. per day till 860° F. was reached. It was then annealed at this temperature for six weeks during which time no variation greater than 2° F. was permitted. Final cooling was started on August 30 and room temperature was attained on January 16. The cover was finally removed on January 21 and the job was done!

During all these months there was no assurance as to what would be found in the annealing furnace when the final "unveiling" took place, because the slightest bit of foreign matter in the glass might start radial cracks which would split the glass into fragments. Too sudden changes in temperature would be equally serious. Mr. Finn and his assistants can now take pride in the fact that the bureau has accomplished a unique and successful piece of work.

Dr. George K. Burgess, director of the bureau, points out that the experience gained for the scientific staff will be of great advantage to the bureau and to any American glass makers who may wish to profit by the results, because all the information obtained is ultimately available to the American public.

The next step toward completion of this reflector is to drill a hole at its optical axis. Although the majority of opticians would refuse to grind a hole in a piece of glass so large as this, except at the owner's risk, on account of the possibility of breaking it, the experts at the Bureau of Standards feel so confident that this can be done without any danger that they will do it at their own risk.

After this the disk will be sent to an optician to be ground, polished and "figured" on one surface until it becomes parabolic. Such a surface has the property of reflecting parallel rays of light to a focus. It is the curve used in automobile headlight reflectors, only in the case of a telescope mirror the curve is so slight that it is hardly noticeable.

With the completion of this disk, Professor Perkins' dream of an all-American telescope will soon be realized.

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THE SCIENCE OF EPIDEMIC DISEASES

By Dr. CHARLES V. CHAPIN

SUPERINTENDENT OF HEALTH, PROVIDENCE, R. I.

It is difficult to define the word epidemiology, as this science is usually called. The common conception seems to be that it is a study of the incidence of the infectious diseases, of their causation and of their prevention. Recently there has been a tendency to extend it to include other diseases, such as cancer and the dietary diseases, as diabetes, pellagra and beriberi. The epidemiologist devotes himself chiefly to the study of disease as it actually occurs in human beings. The bacteriologist and the protozoologist are concerned with laboratory work on the causation of disease. Their business is to discover germs and learn their habits. Bacteriology has been called the handmaid of epidemiology, but it is rather an equal partner. The immunologist studies immunity and means for developing it. The statistician devises formulas and solves mathematical problems. All these may make excursion into the domain of epidemiology and often achieve valuable results. The epidemiologist is especially interested in methods to *prevent* disease, and much of his work is planned for this.

Epidemics have always afflicted mankind and medical men have continually sought to unravel their secrets, but until very recent times there has been little knowledge of scientific method. It is little wonder that preventive measures were based on theory and that theory was arrived at by *a priori* reasoning. Let us consider some of the theories that dominated preventive medicine until well after the middle of the nineteenth century, and are not without influence even to-day.

Ancient Theories

"Epidemic Constitutions"

The theory of "epidemic constitutions," as determining disease, is very ancient. It was clearly enunciated by Hippocrates, the "Father of Medicine," four centuries before Christ. Hippocrates taught that climate has a most important influence in the causation of disease. The air, its heat, its moisture, its impurities, the wind, its direction and force, are powerful factors. Three "constitutions," or types of climate, were described and also the diseases which were observed under each type. Other factors in the environment were discussed by Hippocrates in his chapters on airs, waters and places. Sydenham, in the seventeenth century, elaborated much further the theory of epidemic constitutions. Every known telluric or cosmic factor might be of influence, he said, and he even speaks of the "secret and inexplicable alteration of the air," and of "occult atmospheric influence." Even to-day there are a few epidemiologists who invoke such "constitutions" to explain the spread of disease, but most persons prefer to await the slow progress of inductive science.

Epidemic diseases, like prices, business failures, fashions and fire losses, show great variation in prevalence and by many are thought to occur in cycles, which can be correlated, more or less closely, with sun-spots, climatic conditions, etc. Studies of these relations have yielded little and mystical theories still less.

Whether or not the atmosphere causes disease, it has, through all time, been a popular theory that the air serves as a *vehicle* of infection.

Disease Not Air-borne

When people sicken of smallpox, plague, scarlet fever, measles or almost any infectious disease, it has been believed that it is because some virus, miasm or poison is borne to them by the air. It has been shown that there is some truth in this theory. Thus mosquitoes which transmit malaria are wafted by the air. The tiny droplets of saliva that carry infection may float, perhaps an arm's length, but rarely more. Perhaps infectious dust may be blown a short distance. We now know, however, that the air is a quite negligible factor in the distribution of bacteria and other disease-producing germs.

The Filth Theory of Disease

However, it is another, and far more unfortunate feature of the atmospheric theory of disease, which it is necessary to discuss. This is the supposed relation of decay and filth to disease. Doubtless this is an ancient theory, but until fairly modern times seems to have been advocated by laymen more than by physicians. It is set forth by Lucretius and by Pliny, and was even accepted by medieval monks, though they are not usually considered to have been especially hostile to uncleanliness. This filth theory of the origin of disease has had by far its greatest influence during the last 150 years. Dr. Benjamin Rush, of Philadelphia, was one of its most insistent advocates during the eighteenth century, and his high position as a patriotic citizen and his preeminence as a physician gave his words great weight. His views on this subject were bizarre in the extreme. Almost any organic matter in decay was believed by him to cause infectious and epidemic disease. Not only drains, cesspools and privies fell under his ban, but bilge water, decaying weeds and rotting cabbages were alleged to be the cause of fevers. Decaying matter was judged to give off a death-dealing something, but whether solid particles or gases, ferments or germs no one knew, though there were many guesses, but with few exceptions all were agreed that emanations from filth were the chief cause of infectious disease. Noah Webster, George E. Waring and other American lay writers, as well as the plumbers and sanitary engineers, were warm advocates of these ideas.

Early in the nineteenth century the great reform movement in England came into being. One of its leading figures was Edwin Chadwick. His first aim was to banish infectious disease. To learn how to do this he employed physicians to investigate. They agreed that air poisoned by filth was the cause. Chadwick's legal training did not fit him to act as a scientific arbiter, and, indeed, it is said that he would not listen to counter arguments.

The bacteriologists have taught us that the germs of a few diseases, as of cholera and typhoid fever, are carried from person to person through the medium of human excreta, but neither these germs nor any others breed in this or any kind of filth. The filth theory of the origin of disease is dead. Foul odors do not cause disease. The health officer is not interested in nuisances, unless they involve excreta disposal, nor in plumbing and drainage, unless sewage is likely to flow into a water supply.

The Theory of Contagion

As all are doubtless aware, most of the epidemic diseases are contagious. For the most part, physicians, until comparatively recent times, were not much inclined towards this theory. Hippocrates and Galen ignored it, and ancient and medieval medicine followed their teachings. Some of the Italian physicians, facing the epidemics of plague, during the Renaissance, as Frascatorius (1546), attributed the spread of the disease to contagion. Nevertheless, most physicians before and after him took little stock in contagion, but considered the atmosphere and "epidemic constitutions" as the chief cause of outbreaks of disease. Sydenham denied that even smallpox is a contagious disease, though he admitted that plague is. It is curious that plague was considered the one contagious disease, though in fact it is only rarely directly transferred from one person to another, but is primarily a disease of rats and usually extends to man by means of the bites of rat fleas.

The Jewish method of handling leprosy seems to have been the first application of the theory of contagion to the control of disease, and the Hebrew sacred writings doubtless had much to do with the attitude of medieval Europe towards this disease and perhaps towards plague, the care of these diseases being largely given by the monastic orders. As conspicuous examples of lay acceptance of the theory of contagion may be mentioned Thucydides and Boccaccio. Lord Bacon attributed the pestilence at the "Black Assizes" at Oxford in 1577 to contagion from the prisoners brought from the jail. Richard Mead (1673–1754), one of England's great physicians in the generation following Sydenham, firmly believed in the doctrine of contagion, though he admitted atmospheric corruption. During the nineteenth century, even to the time of Pasteur, the argument continued between the contagionists and those who believed in chemical changes in the atmosphere. Among brilliant examples of the former were Austin Flint, in this country, William Budd, of Bristol, England, and John Snow, of London. They demonstrated with certainty that cholera and typhoid fever are contagious diseases, and Snow argued most convincingly that the virus must be a living germ.

The Germ Theory

It is true that, from the golden age of the Greeks until the time of Pasteur, there have been a considerable number who have supported the germ theory of disease. With few exceptions, however, the theory led to little of practical value, since the nature of germs was entirely unknown. The first conspicuous example of correct deduction was the conclusion of Lister that putrefaction and suppuration in wounds are due to germs similar to those which Pasteur had shown to cause putrefaction and fermentation in broths and infusions. The wonderful success of Lister in applying this theory to surgery did more than anything else to incline medical men to look with favor on the hypothesis that infectious disease, as well as the infection of wounds, is caused by microscopic plants or animals. Still, this was but a theory, and while it remained such, gave rise to the most erroneous ideas as to the *de novo* origin of disease germs, their growth in filth and decaying matter, their wide distribution through the air and their tenacity of life, all of which did much to delay the application of effective methods of control.

Knowledge of Germs Takes Place of Theory

Pasteur and his followers changed all that. The year 1877 may be taken as the beginning of modern preventive medicine, for it was then demonstrated for the first time, beyond the slightest doubt, that anthrax, a disease sometimes affecting human beings, was caused by

living germs. Pasteur and Koch gave to the world the new science of bacteriology. The discovery of germ after germ came in rapid succession until now it has been clearly proved that about a hundred infectious diseases are caused in this way. Scientists often use the term "pathogenic micro-organisms," but I prefer to call them germs, or to use the rather better French word microbes. The majority of these microbes are bacteria, which are decidedly vegetable in character, others are protozoa, lowly forms of animal life, and some are microscopic worms. Bacteria received the earliest and most thorough study of all the germs. Bacteriology is an exacting science and the great number of laboratory men who soon appeared were imbued with the scientific spirit and were trained in logical methods of thought. A great volume of real knowledge of the nature of infectious disease soon took the place of crude theory. A new and wonderful aid had come to the assistance of epidemiology.

Germs Grow Only in Living Bodies

Although 1877, the year of Pasteur's great demonstration, has been named as the dividing point between ancient theory and modern fact in epidemiology, a long time elapsed before the old theories died and men were convinced of the truth of the new discoveries. Though there are even now some doubters, I will venture to mention here some of the more important truths which are now accepted by most epidemiologists as the basis of their science.

Fifty years ago it was vehemently debated whether the virus of disease does not arise *de novo*. When cholera appeared at many points in the Mississippi Valley, in 1873, some thought it imported, some believed that it was a product of our native filth. There was a similar dispute about yellow fever and typhoid fever. Even the germ theorists were in doubt. The question of the spontaneous generation of life has now been settled. All biologists are agreed as to that. Every diesase germ, like every oak and every horse and every human being, is derived from ancestral germs, oaks, horses, humans. Now, if we find a case of cholera or yellow fever or typhoid fever, the epidemiologist knows that it must have come from a previous case, which it is the business of the health officer to find, if possible.

During all time it had been believed that an important if not the principal source of infectious disease is outside the body. The filth theorists thought that their miasms came from an unclean environment. The germ theorists thought that their germs bred outside the body in organic matter. They divided the epidemic diseases into two classes. If the disease poison, or germ, developed outside of the body they called it infectious; if it developed inside the body and was passed from person to person, it was called contagious. When the laboratory men began to study disease germs, they found that it was very difficult to grow them. Some they are even now unable to propagate. It became clear that most disease germs when they leave the body speedily perish, unless they are carefully nurtured in the laboratory by skilled technicians. In rare instances, they may grow for a short time in milk, or some other favorable medium, if all the conditions are right. Formerly, when the health officer found a person with typhoid fever or diphtheria, he sought for the source of the disease in a cesspool or sewer or dung heap. Now he knows he must search for it in some other human being. He knows that nearly all epidemic diseases are contagious. They pass from person to person, though often by a very circuitous route. It perhaps should be mentioned that the germs of a few diseases pass from the lower animals to man, but this is totally different from growing in water, soil, etc. The epi-

demiologist confines his attention to living beings, neglecting dead matter as a source of disease.

Importance of "Carriers" and "Missed Cases"

The laboratory has taught the epidemiologist not only where not to search for the source of disease, but where he should search. The laboratory has shown that when disease germs gain access to a person, they do not always make him sick. He may feel perfectly well, and go about, a healthy "carrier" of disease germs. Again the germs may make their host only slightly ill, causing such atypical symptoms that, even if seen by a physician, the disease would not be recognized, would be "missed" by the doctor. The laboratory has given the physician and the epidemiologist many methods of the greatest value as aids to diagnosis and which help greatly in the search for and study of carriers and missed cases.

Modes of Transmission

The Air

It is not only in finding the sources of infection that the epidemiologist has made great progress, but also in determining modes of transmission. It is not surprising that the air was long considered the chief vehicle of infection, and is to-day by a large portion of the laity. The adherents of the miasmatic theory of disease must necessarily look to the atmosphere as the bearer of the poison, and to the believers in the germ theory it seemed almost certain that such minute particles as germs must be freely wafted by the air even long distances. Since, at that time, the dangerous "carrier" was unknown, the fact that, often, no direct connection between cases of contagious disease could be established almost necessitated the theory that the contagion was air-borne. The demonstration by the early bacteriologists of the extreme smallness of bacteria served to strengthen this view. After a time, however, it was learned that germs are not given off into the air from moist surfaces, such as the membranes of the nose and mouth, the saliva, sputum, the body excretions or from the pustules of smallpox or the skin of scarlet fever patients, or from drains and cesspools. The chief way in which living germs can get into the air is in the tiny droplets given off in loud talking, coughing, etc., and rarely do these float more than an arm's length. It is true that germ-containing material may dry and become pulverized and float as dust, but most disease-producing germs speedily perish on drying, so that little harm is to be feared from dust. Thus the laboratory men have taught us that, under ordinary conditions, and except for a few feet around a coughing patient, the air is a negligible factor in the spread of infection. Lister feared the air as the chief source of wound infection, but modern surgery has shown that it is of little moment. As for our common contagious diseases, the epidemiologists have learned that they are rarely spread through the air, even in the home or in hospital wards.

Contact Infection

As a result of the collaboration of the laboratory and the epidemiologists, it has been fairly well determined that the common contagious diseases are spread chiefly by means of the quite direct transfer of quite fresh infective material from person to person. Doubtless, this is most commonly accomplished by the smearing of saliva and other body fluids on the fingers and on the countless objects which pass freely from hand to hand and from hand to mouth. This is the contact infection of the epidemiologists. Sedgwick, of Boston, was, perhaps, the first to call attention to this as observed during a village outbreak of typhoid fever. He says:

Children abound; and, as there are no fences, and because it is the custom, they mingle freely, playing together and passing from house to house. The families are of that grade in which food always stands upon the table; meals are irregular except for those who must obey the factory bell. The children play awhile, then visit the privies, and with unwashed hands finger the food upon the table. Then they eat awhile and return to play. Or, changing the order of things, they play in the dirt and eat and run to the privy, then eat, play, and eat again, and this in various houses and in various privies. For them, so long as they are friendly, all things are common—dirt, dinners and privies.

It will perhaps be remembered how our army was ravaged by typhoid fever during the Spanish War. A commission was appointed which started out with the idea that the disease must be water-borne. After much study it was decided that contact, direct or through the medium of food and flies, was the cause. Numberless epidemiological studies throughout the world have since made it certain that, in the absence of epidemics due to gross infection of water supplies, quite direct contact is the cause of most typhoid fever.

It is a surprise, and rather shocking, to learn that the human hands are so often the carriers of excrement, yet that it is so is abundantly proved by both bacteriologists and epidemiologists. Who can doubt that the fingers are ten times more likely to be smeared with saliva, and that they play the chief part in the spread of our most common diseases, in which the secretions of the mouth are the chief source of infection.

Other methods of transmission are by food and drink. Thus living typhoid germs or cholera germs may be carried many miles in milk or in water. The control of such modes of conveyance has resulted in an enormous decrease of those diseases which were formerly commonly spread in this way, though serious outbreaks sometimes occur even now, as is shown by the sad experience of Montreal with typhoid fever last year. Our knowledge of these modes of disease transmission are due almost entirely to studies by the epidemiologists.

Insect Transmission

Another fact of the utmost importance to epidemiology and to the prevention of disease is that certain contagious diseases are spread by biting insects. That insects play a part in disease transmission has long been suspected by a few. Mitchell, Nott and King in this country, Finlay in Cuba, Beauperthuy in South America, Manson in China, and others suggested the theory that mosquitoes transmit the virus of malaria and yellow fever and filariasis. Theobald Smith, in this country, in 1893, was the first to prove definitely that a disease may be transmitted by insects and to show how it is brought about. He demonstrated that Texas cattle fever is spread from animal to animal by a species of tick. Among the more important diseases transmitted by insects may be mentioned malaria, yellow fever, bubonic plague, typhus fever, dengue and African sleeping sickness. The development of our knowledge of these diseases furnishes the most fascinating chapter in medical history.

Immunity

From ancient times it has been known that in most contagious diseases one attack protects against another. Even influenza seems to produce some immunity in many of its victims, though it is usually far from complete or lasting. It is only in quite recent years that we have learned that it is by no means always necessary for a person to have a typical attack of a contagious disease to acquire immunity. Many times, persons have such a mild attack of diphtheria or scarlet fever that it is unnoticed, but the immunity may be as complete as that following a severe case. Again, it is now well known that, in most contagious diseases, a still larger portion of the population acquires the germs without

being sick at all. They are merely carriers, but are, nevertheless, immunized by their germs. It is believed that the amount of such natural immunity in a community is one of the important factors in determining the course of outbreaks. In large towns and cities, where one's contacts with others are so frequent, the number of such immunes is usually very much larger than in rural districts. In our mobilization camps recruited from rural districts, the outbreaks of contagious disease were sharper and far more extensive than in camps recruited from cities where so many had become immune.

It has been a common observation, and one that puzzled epidemiologists, that very young infants are less susceptible to contagious disease than they are a few months later. Now we know that the human body, when attacked by the germs of disease, begins to protect itself by the manufacture of antibodies, that is, antidotes against the germ poison. In diphtheria the antibody, or antitoxin, can be measured and we know that it continues in the blood long after the germs have disappeared. The blood of many mothers contains diphtheria antitoxin, and it passes to their unborn babes and is also furnished in the milk after birth. The same thing undoubtedly happens in many other diseases. This explains the comparative immunity of new-born children.

Ever since the discovery of vaccination against smallpox, medical men have sought immunization against other diseases, but it remained for Pasteur to show the way. Successful methods are now employed against several diseases, as diphtheria, typhoid fever, scarlet fever, dysentery, cholera, plague, measles and rabies. The laboratory man devises the methods and the health officer applies them, but to the epidemiologist falls the duty of appraising their real worth.

Field Work

Among the methods employed by epidemiologists in their study of disease, none has been so fruitful as what may be called field work. An exceedingly important study of this kind was made by John Snow, of London, about the middle of the last century. It was then almost universally believed that cholera is spread by a miasm from polluted soil. A severe, but sharply localized, outbreak of cholera occurred in St. James's Parish in early September, 1854. There were far more deaths than in any other similar district in London. A dozen different conditions, such as overcrowding, ventilation, cleanliness, sewers, water supply and nuisances had been investigated by the authorities without result. Snow obtained the location of all cholera deaths in the parish and plotted them on a map. There were several public wells which supplied different districts. It appeared that the great bulk of the cases was nearer the Broad Street Pump than any other. Investigation showed that many of the patients, a little outside the district, also went to the Broad Street Pump, because the water was colder. An almshouse and a brewery in the midst of the district, which had wells of their own, were almost exempt from infection. Two women in the West End who had water sent them from Broad Street developed cholera. A visitor from another town who remained in the district only twenty minutes, but who drank from the well, soon sickened of the disease. Snow rightly concluded that the well was the source of cholera, and had the pump handle removed and the outbreak, which was declining, soon ceased. Similar studies were made by Snow in connection with the various municipal water supplies of London, which are derived from various sources. By studying the distribution of the cholera cases, he found that the case rate

on one supply was five, on another seventy-one, on a third 288. The last was the most polluted, the first the least polluted. Similar studies all over the world have demonstrated the very great importance of water as a distributer of the germs of cholera, of typhoid fever and of certain other diseases.

At the time of the American Revolution there was a country physician in Gloucestershire, England, named Edward Jenner. He was an observing, thoughtful man, who had friends among the ablest medical men in London. He soon learned that the cows around about occasionally had a slight disease called cowpox, characterized by a few vesicles on the udder. Farmers and dairymaids occasionally contracted the infection, the vesicles appearing on the hands. It was a tradition among the country people that such persons could never contract smallpox. Jenner wisely did not disregard this tale, but for years kept his eyes and mind open. He found many persons who had had cowpox, but who never contracted smallpox, though exposed to it. At this time it was common practice to inoculate persons with smallpox, because they thus had the disease in much milder form than when they contracted it in the ordinary way. Jenner, as occasion offered, inoculated with smallpox many persons who had had cowpox recently, or in former years. None contracted smallpox. Jenner also found that cowpox, or vaccinia, as he named it, could be easily transferred from person to person. In May, 1796, he thus "vaccinated" a young boy and two months later inoculated him with smallpox. He did not develop the latter disease. A great many similar tests were made of the new procedure, both in Europe and in this country. Though an abundance of statistical evidence and personal experience, running over more than a century, has demonstrated the worth of this achievement, no more conclusive evidence was needed than the inoculation with smallpox of groups of persons living together, some of whom had been vaccinated and some not. It was invariably found that the vaccinated did not contract smallpox. The others did.

During 1889, influenza, which had been absent for many years, appeared in Russia and, within about three months, spread completely over Europe and America. Its progress was so rapid that to many it appeared that it must be airborne, even across great ocean stretches. Parsons, in England, determined to find out. He got the facts from great numbers of isolated communities, among others from four hundred off-shore lighthouses and lightships and from thousands of seagoing vessels. In not one instance was one of these attacked by influenza without human intercourse with the land. In a similar manner it was shown that isolated hamlets and dwellings among the Alps had no influenza until after the arrival of a visitor. Influenza is surely not an airborne disease.

There is one very important disease which I might be criticized for including among the germ diseases, for it is caused by an extremely minute worm. I refer to the results of infestation by hookworms. However, this so resembles the diseases we are considering that it is fair to refer to it here. These worms have long been known, and it was also known that they caused some disturbance of the health of workers in certain mines. No one imagined that the disease could be a scourge of whole countries until Ashford, one of our army physicians, in 1899, began to study the very prevalent anemia in Porto Rico. It was speedily found that, not only in Porto Rico, but in our southern states, and also in most warm climates, hookworms cause a vast amount of disability. A simple way was soon found to free the patient from the worms. It was also found that if human excrement is properly disposed of, there will be no hookworm disease, but to con-

trol it simply and economically has required an immense amount of epidemiological study of the distribution of the worms, of the temperature and rainfall, of the nature of the soil, of the manner of infection, of the amount and persistence of the infestation and of the success of methods of treatment and of excreta disposal. To discover the essential cause of a disease is one thing. To find effective means of control is quite another. To plan and test such means is the province of epidemiology.

Animal Experiment

Much field work, as in some of the examples just given, was done before the germs of the diseases were discovered, indeed, before microbes and their disease-producing powers were known at all, but it is, nevertheless, true that the labors of Pasteur and of his countless laboratory followers have piled up a wealth of knowledge about disease germs which has been of tremendous value in all epidemiological study. The greater part of this knowledge has depended on the use of small animals, as mice, guinea-pigs and rabbits. Only a very few diseases spread naturally among both humans and animals. In this climate tuberculosis is almost the only common disease which does so; nevertheless, such animals may be of the greatest use. Thus, though guinea-pigs are not naturally subject to diphtheria, the inoculation of the germs causes characteristic symptoms, and the discovery of antitoxin and immunization against this disease depended almost entirely on the use of these animals. Also animals have been much used for feeding and inhalation experiments for the study of the modes of transmission of tuberculosis.

Bubonic plague, which is such a tremendously destructive disease to man in many parts of the world, is common also among various kinds of animals; indeed, it is primarily a disease of rats, secondarily attacking human beings. Probably the plague problem would never have been solved without the discovery of the germ of the disease, which was made simultaneously by a Japanese and by a Frenchman, in 1894, but this discovery itself amounted to little. It would be interesting, indeed, to follow the various field observations which led to the theory that the disease is carried from rats to man by fleas, but space forbids. I will simply refer to the brilliant experiments of the English Plague Commission, which were carried out in India and which demonstrated the fact beyond question. The inhabitants of a plague-stricken village had abandoned it, as often happened. Guinea-pigs were then allowed to run about some of the houses. Many of them speedily died of plague and rat fleas infected with plague germs were found upon them. Other guinea pigs were exposed in boxes covered with netting to exclude fleas and none had the disease. Others protected from fleas by tanglefoot placed around the cages also remained well. Others, still, were exposed to soiled clothing in infected houses, but remained well, except in the few instances in which fleas happened to remain. The problem of plague was, after centuries of speculation, solved by a few simple experiments.

Experimental Epidemiology

This is the technical name of a rather new method of study which is proving of very great value. It is less than ten years since Topley, in London, began a series of experiments dealing with the spread of contagious disease among mice. Occasionally experimental epidemics among laboratory animals had been studied before, but this was the first time an extended series of experiments had been carried out in the attempt to solve some of the general problems relating to the rise and fall of epidemics. Previous work had been to solve some particular problem concerning some particular disease. It is

curious that, a little later, a quite similar series of experiments was begun at the Rockefeller Institute, in New York, without any knowledge of what was being done in London. It is also of interest that, since the two groups of investigators became acquainted with each other's studies, they have worked on their problems in complete harmony and with constant cooperation, though the character of the experiments on the two sides of the ocean has varied considerably.

When a cage of mice is infected with mouse typhoid, or certain other diseases, a little time must elapse before the epidemic gets into full swing. After awhile it begins to decline and gradually dies out. The reason for its dying out is that the surviving mice have been immunized by non-fatal doses. Now, if a batch of susceptible mice are added to the immune herd, in a short time the added mice begin to die and another epidemic occurs. At first the survivors of the first outbreak resist the new wave of infection, but after a time some of them, too, succumb. Much light has already been thrown on the problem, but many of the facts observed in these experiments are difficult to understand, and they are still under investigation.

Since the development of bacteriology many have been inclined to forget that, as it takes two to make a quarrel, so it takes two to make a disease, the microbe and its host. There is a constant struggle between disease germs and the bodies of animals and of human beings that they invade. There is also a tendency for an equilibrium to become established. The germs kill off the most susceptible and immunize the more resistant. In some of the resistant individuals the germs become more or less firmly established, thus producing carriers, which carry over the virus until more susceptible material is available. This group of experiments has forcibly called attention to this tendency to equilibrium, and to the importance of carriers and of herd immunity in the rise and fall of outbreaks of contagious disease. Much light also is thrown on changes in the virulence of the germs and on the effects of the dosage of the germs and on the diet of the animals.

Commander Dudley, of the British Navy, has been making careful studies of outbreaks of diphtheria, scarlet fever and influenza on shipboard, and in boarding schools, where conditions can be controlled, somewhat as in the cages of mice. He comes to conclusions very similar to those of Topley and Flexner and their coworkers. As in mice, so in humans, carriers play an important part in the causation of outbreaks. Natural immunization, largely by doses of the virus too small to be infective, increases the immunity of the group and brings outbreaks to a close and then the addition of newcomers starts the disease again. Dudley, more convincingly than any one else, showed the immunizing effect of continued slight exposure to cases or carriers. In the Royal Naval School at Greenwich he found the immunity to diphtheria, as indicated by the Schick test, significantly higher in boys who had been through an outbreak of diphtheria in the school, without themselves contracting the disease, than it was in a comparable group of boys who had not been similarly exposed to diphtheria.

Experiments on Human Beings

A number of important epidemiological facts have been learned by experiments on human beings, sometimes accidental, sometimes deliberately planned. Scores of times in various laboratories pure cultures of disease germs have been accidentally drawn into the mouth or nose of some one, or have gotten into cuts in the skin and have caused disease. Cholera, typhoid fever and diphtheria have thus been caused in different parts of the world, and no better proof is

afforded that these germs are the true causes of these specific diseases. There is a considerable list of disease germs, the virulence of which for human beings has been proved in this manner.

At other times the infection of human beings has been intentional. Many investigators have made tests on themselves, and many persons have volunteered for the experiment, sometimes with and sometimes without pecuniary reward. The most conspicuous example of such experiments is that made during the study of yellow fever by our army commission in 1899 and 1900. The observations of Dr. Carlos J. Finlay, of Havana, had shown that a certain mosquito, now called *Aëdes egypti,* is particularly numerous where yellow fever abounds, and he suspected that it was the cause of the disease. Henry R. Carter, of our Public Health Service, had observed the curious fact that, though the incubation period of yellow fever is about five days, there was always an interval of fifteen to twenty days after yellow fever was brought to a new place before secondary cases developed. The commission thought that perhaps this might be due to the time necessary for the growth of the germs in the mosquito, so they determined to take up first the mosquito question. Yellow fever was continually taking its toll of victims in Havana, so that considerable risk was warranted. The question of mosquito transmission could be speedily settled by testing it on human beings. Two members of the commission and a number of other volunteers allowed themselves to be bitten by mosquitoes which had previously bitten yellow fever patients. Most of the men developed yellow fever, and some of them died, including Lazear, of the commission. Their sacrifice has already saved vast numbers of lives and untold wealth. In all, twenty-four persons acquired the disease by voluntary exposure to the bites of infected mosquitoes. The experiments carried on in the most careful manner proved, beyond question, that this disease is spread from man to man by the bites of mosquitoes. They did not prove that the disease was not also spread by means of the excreta or the effluvium therefrom, as was believed by practically every one who had experience with this disease. So rooms were prepared in which the floor and bedding were soiled with vomitus and feces from patients, and heaps of clothing from the dead were thrown in the corner. Volunteers slept in these rooms night after night. Not one developed the disease. The mosquito theory had been established. Gorgas put it to a practical test. He eliminated *Aëdes egypti,* and yellow fever, for the first time in 150 years, disappeared from Havana. The great terror of the Western Hemisphere has been banished from the American continent, except for one small area in Brazil. Epidemiology did this without any knowledge of the nature of the germ which causes the disease.

In a similar manner a large number of persons assisted in the demonstration that malaria is mosquito-borne by submitting themselves to the bites of infected insects. The most striking proof was afforded by shipping from Italy to England (where there was then no malaria) mosquitoes which were infected with malaria in Italy. Mr. P. T. Manson, of London, son of Patrick Manson, who had done so much to help Ross in his malaria studies, allowed himself to be bitten and developed malarial fever, and malarial germs were found in his blood.

Intentional inoculation of supposedly infectious material into human beings has also been tried in scarlet fever, measles and influenza.

Mathematics

The importance of statistical records in epidemiology is very great. They are, in fact, its chief raw material.

Often these data are of value just as they are, or after being subjected to very simple mathematical treatment. Thus, a health officer of a growing city who can show from his death records that there were 122 deaths from typhoid fever in 1882, and none in 1922, has no need to do more to prove that fatal typhoid fever has shown a phenomenal decrease. If the city has been growing and the decrease in deaths has not been large, it may not be so evident, and he may have to calculate the rate, that is, the number of deaths per one hundred thousand of the population, before he can be sure of the decrease and especially of its amount. Again, suppose a health officer wishes to know how often a second case of infantile paralysis occurs in a family. If he has had an outbreak of one hundred cases, and four of them are secondary cases, is he justified in assuming that four is the correct percentage of secondary infections? By no amount of thought can he determine whether it is or whether he ought to have twice or ten or a hundred times as many cases before he can be reasonably sure of the secondary attack rate. There are, however, mathematical formulas which will inform him, within reasonable limits, how large a sample he ought to have. If one thousand soldiers have been immunized against colds and have been followed through the winter, and it is found that 586 contracted a cold, while 702 of one thousand not immunized soldiers living under the same conditions suffered from colds, is the difference sufficient to warrant the conclusion that such immunization is of value? Here again statistical methods will help in determining the probability. In studying the possible causative relation of events, mathematics are of much value to the epidemiologist.

There are, however, certain persons who have gone very far in their attempts to solve epidemiological problems by means of mathematical formulas. Using the statistical material furnished by health officers and registrars, they, by such formulas, attempt to solve some of the most difficult problems of causation, such, for instance, as the causes of the great decline of the tuberculosis death-rate. Again, they claim to be able to establish the true periodicity of diseases. Thus it is alleged that influenza occurs every thirty-three or sixty-six weeks. In the opinion of many persons competent to judge, it is believed that some of these refined statistical methods are not suitable for the solution of many of the health officers' problems, and also that they have not, as yet, led to establishing many epidemiological facts of importance.

In the statistical analysis of records of cases and deaths it must also be borne in mind that the conclusions reached are only as sound as the data on which they are based. Thus, if three fourths of all cases of scarlet fever are reported in one city and two thirds in another, it is obvious that no refinement of statistical method can make the two series of figures comparable, so long as the completeness of the reporting remains unknown. A certain familiarity with statistical methods will help the epidemiologist to avoid many pitfalls in the interpretation of his figures, but it is upon the proper selection of data, the careful use of controls, and interpretation consistent with the known facts of the disease in question that the soundness of epidemiological studies really depends.

Results

The study of epidemiology has profoundly modified our methods of dealing with contagious diseases. The old methods of arbitrary detention and destructive disinfection of incoming vessels has given way to effective inspection and removal of contacts. Fumigation is reserved only for plague ships, and is not destructive. On shore the fumigation of dwellings and schools also has been

abandoned. The useless search for disease in drains and cesspools has ceased, and the search for human carriers in homes, schools, institutions and dairies finds the true sources of infection and permits control. A wet sheet is no longer hung before the door of the sick room, but the attendants are taught to wash their hands even as the surgeon does. Persons do not cross the street when they see a scarlet fever warning sign, nor is it necessary to place an isolation hospital in a lonely spot. All our methods of isolation are becoming more rational and effective and less of a burden on the afflicted.

Cholera is no longer feared and typhoid fever is a vanishing disease. The discovery of the germs of these diseases has been of great assistance to the epidemiologist, but before the days of Koch and Eberth the source and mode of spread of these scourges had been largely worked out. The efficiency of water filtration, of pasteurization of milk and of immunization have been tested by the epidemiologist, and their worth has been proved. Epidemiology has furnished the weapons to the health officer, and politics alone can prevent their successful use.

The imminent extinction of yellow fever is due entirely to epidemiological studies.

The ancients could combat malaria only by drainage, a measure rarely feasible. Epidemiology, by making use of the discovery of the germ by Lavaran and of the infecting mosquito by Ross, has studied the vast problem in detail, and has devised and tested other methods of control, so that now it is possible to rid even large rural areas of this disease, where even a few years ago the task seemed hopeless.

For sixty years the discovery of hookworms did little for mankind. The epidemiological studies begun by Ashford, and continued by the Rockefeller Foundation, have brought good health to millions of men and women.

Besides these especially noteworthy results, the scientific study of the causes and of the modes of transmission of many other infectious diseases have been of immense importance in their control. Moreover, epidemiology has not confined itself to this class of diseases. Pellagra was formerly thought by many to be a germ disease, but careful epidemiological studies have shown that it is not, but is due to some dietary deficiency, and, though much more needs to be learned, the disease can generally be prevented and cured, too, by a proper diet.

Even if we are still helpless when influenza comes, if we can not stop the spread of measles, or whooping cough, if pneumonia remains a very serious problem and we are still in doubt how much the spread of scarlet fever and diphtheria has really been checked, let us take courage. Remembering what has been accomplished during the last fifty years, are we not justified in the hope of other great advances in the half century next to come?

A VISIT TO FABRE'S *HARMAS*

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Now that scientific research has accumulated, almost within the last quarter of a century, an entirely new and astonishing amount of knowledge concerning the vital relation to man of those small creatures we call insects, the world has become much interested in the activities of these animals and in the rôle they play in the world. Since it has been conclusively demonstrated that fleas, mosquitoes, houseflies, body lice and other insects carry the unseen organisms that cause some of the most malignant diseases to which man is subject, we have begun to look upon these tiny creatures with more than passing interest; and upon the men who are devoting their lives to a study of them with considerable respect. But long before investigators discovered that insects are the carriers of disease-producing organisms which interfere seriously with our health and happiness, there were men who were interested in these small animals and were painstakingly observing them and their ways, solely because of their great inherent scientific interest—because they exhibit a most amazing variety of habits, adaptations, instincts and modes of living. Such a one was Jean Henri Fabre, of modest, humble character, but profoundly devoted to a search for the truth.

Victor Hugo, in an appreciation of Fabre, called him "the Homer of the insects," while Edmond Rostand, in a subsequent eulogy of the man, bestowed upon him the title, "the Virgil of insects." Neither of these titles is adequate, for each expresses but one of Fabre's gifts, namely, that of a story-teller and writer, thus failing altogether to convey any notion of his other great quality, his transcendant obsession for observing the ways of nature. From his childhood Fabre was obsessed with a passionate curiosity concerning the lives and ways of living creatures, especially insects. Born of illiterate parents who utterly failed to comprehend their remarkable child and whose superstitious notions were aggravated by the worthless stones and queer creatures the "little simpleton" brought home in his pocket, as though "some one had cast an evil spell over him," he pursued his way without sympathy, amid much unrequited toil, persistently following his search for truth to the very end of an eventually fruitful life. His early boyhood was spent on the high, barren, sterile pasture lands of Provence in Southern France, where the struggle for existence was terrific.

Indeed Fabre's whole life was a tremendous physical struggle, yet it was, from his young manhood at least, one succession of happy, glorious, exciting days, intellectually. Probably most of us in our usually superficial way would say that Fabre was too impractical to meet with any degree of material success the struggle for existence with which he found himself confronted. The truth is, his spiritual qualities were too insistent and his absorption in a persistent search for the truth too complete for him to give much material thought or effort to the morrow of life. As a result, the grim specter of want skulked just around the corner from his door nearly all his long, eventful life. But no one can say that the man who has the fire of scholarly research and answers

to its call within him could not attain material success if he cared to put away the former and enter with zeal upon the pursuit of the latter. It is not too much to say that the human qualities requisite for success in either field are much the same—singleness of purpose, fidelity to truth, imagination, faith, work, and again, work. It seems passing strange that a man with the high ideals of Fabre and the courage to follow them against all adversity should suddenly emerge from such a humble, barren, inhospitable environment and stand like a towering, weather-beaten but sunlit butte on a bare, lonely plain. He was unable to explain it, for he always believed himself to be a living refutation of that portion of the theory of evolution which holds that heredity and environment largely determine what a person's character and ability shall be; but de Vries' work on mutations and the knowledge of Mendel's experiments on the dominant and recessive qualities of hybrids came too late for Fabre to appreciate the full significance of them and their possible application to his own existence.

Nimîs, the largest city in the general region of Provence, was the terminus of the great Roman road that left the imperial city through the Porta dei Cavalleggeri over the Aurelian way, skirted the Mediterranean through northern Italy and passed along the Riviera of France for the most part where that fine modern road, the Grand Corniche, now runs. Over this road during the first centuries of the Christian era came the flower and culture of Rome, pouring into the Valley of the Rhone which became the center of Roman civilization in Southern Gaul, with Arles as the capital and with Nimîs, Avignon and Orange as outlying cities. Hardly had the development of this Roman province come to its fruition before the cruel, crushing Goths arrived in the fifth century and overran Provence, capturing Arles and completing the destruction of this outlying seat of Roman civilization. The triumph of the Goths was short-lived, however, for they were overwhelmed some two hundred years later by the Saracens, who in turn were expelled by Charles Martel in 739 when the country came again under definite Frankish rule. Amid all this welter and chaos of races, in which there must have been more or less mingling of many bloods, who can say that an intellectual strain of Roman culture, recessive for centuries, did not suddenly reappear in Fabre, or that its incipient potency did not burgeon forth as a mutation to produce this naturalist? We only suggest the idea, we do not argue it, for it matters little how he came, but that he was here does mean much to humanity.

Fabre's schooling during his early boyhood days was meager, poor in quality and obtained at a sacrifice of physical strength. His thirst for knowledge and his great industry carried him through these early years and in 1842, at the age of nineteen, he acquired a diploma to teach in elementary schools and obtained a position as teacher in the "college" of Carpentras. Fabre was a born teacher and at once gained the interest and respect of his pupils by the vivid, living manner in which he taught chemistry, physics and geometry. In the meantime, ambitious for a professorship in a real college, and imbued with a desire for research, he studied during the long evenings and every spare hour of his holidays to perfect himself in mathematics and the sciences while he struggled to maintain life on a pitiful salary of seven hundred francs a year. The opportunity for which he was preparing came at last, for early in 1850 he was invited to occupy a vacancy in the department of physics and chemistry in the College of Ajaccio, in Corsica, where he became greatly interested in the flora of the island and made an extensive collec-

tion of the native plants. Suffering severely from malaria, however, he was glad, after three years of service at Ajaccio, to accept a call to the chair of adjunct professor of physics in the Lycée at Avignon. Thus he returned to the region in which he had been born and reared. Here he taught and carried on his laborious researches on living insects, happy in the opportunity to live, to "pry into life," and to observe nature under the blue sky of his native land; for it was while in Avignon in 1854 that he chanced to fall upon an entomological treatise by Leon Dufour which so enthused and engrossed his mind that he at once began those remarkable studies of his on the habits of living insects which finally came to occupy his whole time and thought to the very day of his death.

As a teacher, Fabre thought that natural history should be taught from nature itself and not from books. He also believed it might be taught to girls as well as to boys. In this respect he was far ahead of his time and, as the sequel shows, suffered for it from the persecutions of those bigoted, intolerant individuals who were not able to see beyond the tiny horizon which bounded their restricted lives. The minister of education, Monsieur Victor Duruy, instituted about this time in the schools of France courses for the higher education of girls, a distinct innovation for those days. In the Lycée of Avignon these courses in the physical and natural sciences were assigned to Fabre. The girls were eager, enthusiastic and receptive, but Fabre soon found that to teach girls the composition of air and water, the nature of electricity, the manner in which a seed sprouts or a blossom opens was an abominable corruption of virgin innocence and must therefore be stopped by fair means or foul. Unfortunately, Fabre had no lease of the house in which he lived, a condition of which his persecutors took full advantage; for one morning in the summer of 1870 the bailiff appeared at Fabre's home and bluntly informed him that he must vacate the premises within four weeks from date or his household goods would be set into the street. By chance the only house he could find available was one in Orange, a small city some twelve miles north of Avignon. Thence his family and household goods were removed, thanks to the aid of a generous loan of three thousand francs made by John Stuart Mill, who had spent many happy days with Fabre roaming through the fields about Avignon where they had together collected the native flora in which both were interested. Although Fabre still held the curatorship of the Requien Museum at Avignon which furnished a small yearly stipend he had now to look about for further sources of income for the support of his increasing family. Thus necessity forced him to begin that series of elementary textbooks of science which, written in his inimitable style, proved so popular with both young and old that the royalties from the sale of them were, at that time, and to Fabre, unexpectedly remunerative. Here also, at Orange, was begun his great work, the "Entomological Souvenirs," which brought world-wide recognition and permanent fame to the author. His residence in Orange, however, did not prove to be permanent, for he was destined to make one more move which he determined would be his last one. The cause of this final change was characteristic of the man and was the natural outgrowth of his love for nature and his desire to observe the habits of insects unmolested by curious passers-by.

The road leading up to the house which Fabre occupied in Orange was bordered on either side by a row of fine plane-trees which had afforded welcome shade in summer and homes for birds, cicadas and other insects in whose songs

JEAN HENRI FABRE.

THE FABRE FAMILY

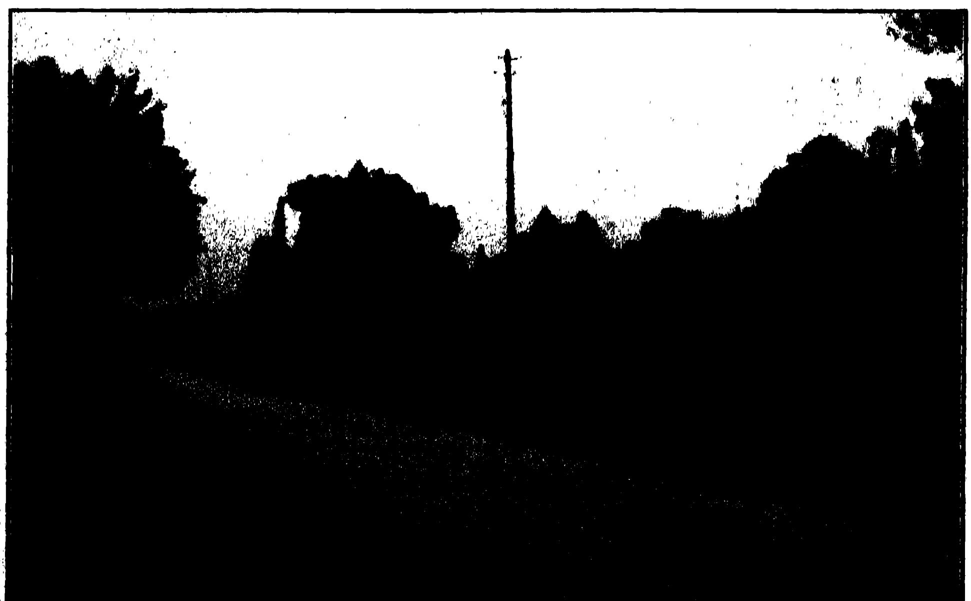
FIRST ROW, SITTING—MLLE. FABRE (CARETAKER OF HARMAS), FABRE'S BROTHER, J. H. FABRE, MADAME FABRE (SECOND). SECOND ROW, STANDING—MLLE. FABRE, DAUGHTER OF THE SECOND MRS. FABRE, PAUL AND EMIL FABRE (SONS OF FABRE), EMIL FABRE'S SON, MLLE. FABRE, DAUGHTER OF THE SECOND MRS. FABRE. PHOTO TAKEN IN 1905 OR 1906.

and presence he so delighted; but the owner of the place, having little of the romance and love of nature in his soul, appeared one morning with workmen and tools and felled and disposed of every one of the cherished plane-trees. To Fabre it was an act of vandalism and so disheartened and disgusted him that he resolved then and there to acquire a place of his own where no trespasser could interrupt his observations and where no ruthless owner could cut and destroy. Thus was born the idea of the "Harmas," which Fabre was now enabled to make a reality through the income from his writings. From his love of the fields and his desire for quietness he went to the little village of Sérignan, five miles northeast of Orange, and purchased a deserted house with its bit of neglected and overgrown garden situated some little distance from the center of the village, in a quiet, somewhat isolated spot. Here, then, at last, he had acquired "the bit of land long cherished in his plans to form a laboratory of living entomology, the bit of land . . . in the solitude of a little village," his "harmas," which was to become, all unsuspected by him, the mecca of many an admiring fellow-worker.

On a beautiful day in April the writer, on a pilgrimage to Fabre's Harmas, alighted at the station in the quaint old city of Orange with its interesting re-

mains of a Roman Theater and its amazingly well-preserved Arc de Triomphe. By dint of inquiry we learned that an autobus made two round trips daily between Orange and Vaucluse, the latter town of particular interest because it was here that Petrarch spent several years of his middle life in the solitude of his quaint old home not far from the shimmering pool from which the river Sorgue takes its source. In going from Orange to Vaucluse the bus passes through the village of Sérignan, where it stops long enough to discharge and receive its infrequent passengers and to deposit the morning's mail. Leaving La Gare of the P. L. M. at Orange, we passed uptown by way of the Hotel de La Porte et des Princes, along the Rue Victor Hugo, around the Arc de Triomphe, and on out into the country where the hard, white road, lined on either side with plane-trees, led through olive orchards and vineyards until suddenly it came into the *Cours* J. Henri Fabre; and in a moment more we found ourselves in the village square, facing the bronze statue of Fabre reposed in a sitting posture and wearing the broad-brimmed hat he always affected.

Sérignan is a sleepy little cross-roads village, composed mainly of petty tradesmen and mechanics—a blacksmith, a cabinet maker, a wheelwright, a bicycle mender, a carpenter, a baker—whose main business seemed to be to serve the peasant farmers in the immediate neighborhood. There is the inevitable church, cathedral-like in its dim, cold, spacious interior, the Hotel de Ville, the Poste et Télégraphe, a tiny shop displaying a few cheeses, some dried fish and a few staple vegetables and one equally tiny shop in which the village housewives purchase needles, thread, yarn for knitting, towels and other simple household necessities. The streets are narrow and crooked, the houses are old, quaint stone and tiled affairs with a few tiny windows and are built in all sorts of shapes and set in apparently any position that suited the fancy of the builder. The only modern touches in the village were



THE WALL OF THE SIDE OF THE HARMAS NEXT TO THE STREET.

THE FRONT OF FABRE'S HOUSE IN HIS HARMAS AT SÉRIGNAN.

some wireless antennae stretched across the roofs of half a dozen houses, an air-plane droning overhead, and the small wasp-like autos kicking up clouds of dust as they honked through the streets.

Suddenly, as I stood taking a snapshot of the village square and statue, a kindly Frenchman appeared on a wheel, quickly dismounted and came directly to the stranger, for he too was a photographer, and an admirer of the man to whom he was sure the American had come to pay homage. Monsieur Raymonde quickly introduced himself and enthusiastically offered to conduct me to the Harmas, for he knew the way, was acquainted with Mademoiselle Fabre, and, what was more wonderful to the stranger, he had often visited Fabre while the latter was living and working. Thus I was personally conducted to and through the Harmas and, at the same time, entertained with reminiscences of the entomologist whose laboratory I had come to visit. From the

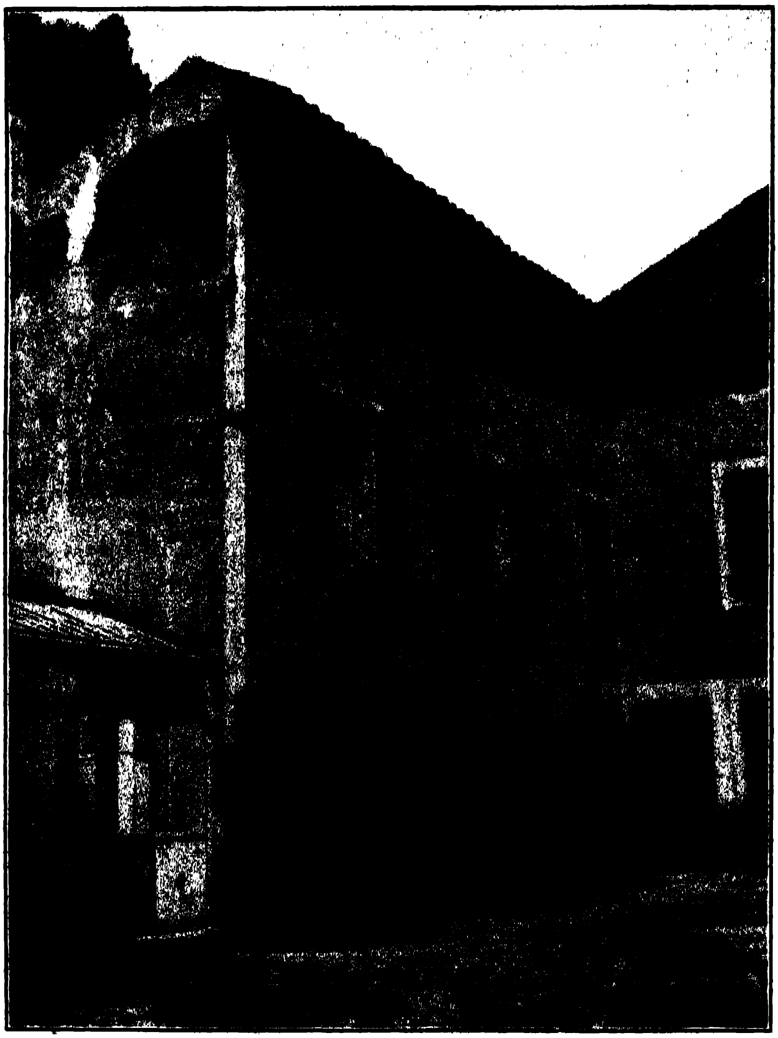
village square we turned back toward Orange for perhaps three quarters of a mile until we came to an isolated place among the unkempt fields somewhat pretentious in appearance, for it was surrounded by a high solid stone and concrete wall. Just within the wall in the corner facing us as we approached was a cluster of the dark, conical cypress trees so characteristic of Southern Europe through which one could see the tiled roof and patched stucco walls of the dwelling. We passed down a narrow path along the north side of the harmas until we reached a plain wooden door set in the wall. My guide pulled the end of a wire beside the door and we heard a bell tinkling in the distance which was promptly answered by a tiny servant girl, who ushered us into the quiet protected precincts of the bit of land where Fabre spent thirty-eight years of his later life observing the insect inhabitants and writing of their curious lives. The word, *harmas*, as he explains, is "given, in this district, to an untilled, pebbly expanse abandoned to the vegetation of the thyme. It is too poor to repay the work of the plough; but the sheep pass there in spring, when it has chanced to rain and a little grass shoots up. . . . This cursed ground, which no one would have had at a gift to sow with a pinch of turnip seed, is an earthly paradise for bees and wasps." Such it was when Fabre found it, but on this April day we stepped through the opening in the wall into another world, a world fragrant with the aroma of the native spring flowers, quiet, peaceful and permanently restful.

As we passed through the tiny doorway we entered a broad lane, or way, which, beginning beneath a locust tree entwined with climbing roses, led straight on by the great water basins on the left and passed beneath two fine plane-trees in front of the house where it widened a little, and then continued on between rows of blooming lilacs on either hand to the great iron gate in the front wall which gave entrance and exit when needed but was opened only on special occasions.

At the house we were received by Mademoiselle Fabre, the oldest daughter, who has been designated caretaker of the place now that it has become a public memorial under the care of the state. She had chairs brought and we all sat down under the wide plane-trees in front of the house, where we chatted about her father and his work. Mademoiselle is petite, with whitening hair, and rather frail in appearance with her thin and wrinkled face and hands, but her mind is alert and questioning. She evinced none of the usual French vivacity of manner, yet it was evident that she was proud of the visit from the American, feeling that it was an act of homage to her father.

The broadened space in front of the house was shut off from the garden of the harmas by a low stone wall ornamented with urns and trailing vines. A passageway in it led down to the brimming pool with its tinkling fountain where aquatic insects were skipping over the surface and diving into its depths. We were scarcely more than seated before Sophie, the venerable tortoise who has been since the garden first began, came stumbling up the stone step from somewhere in the tangled shrubbery below, and made straight for the felt slippers of Mademoiselle at the soles of which she nibbled, whether as a request for food or as a turtle's mode of caress I could not tell; and if Mademoiselle knew she did not explain but gently shoved her turtleship away as the attack was renewed or lifted her feet to the round of the chair out of reach.

The house is a simple, square, two-story dwelling with a wing on either side, of which the left one constituted Fabre's laboratory, supplemented by the



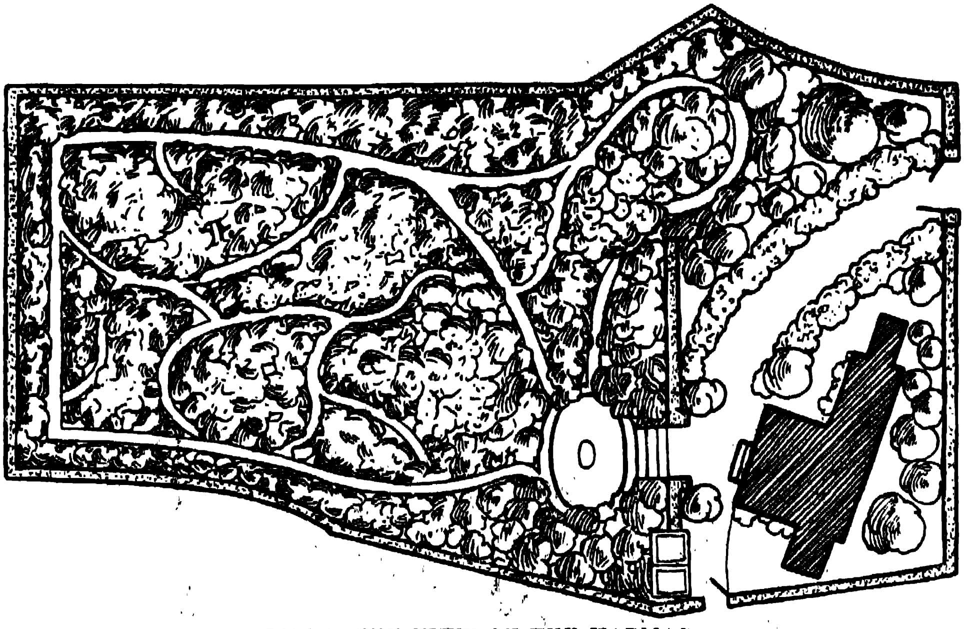
THE ELL OF FABRE'S HOUSE IN WHICH HE HAD HIS WORKROOM OR LABORATORY.

glass house adjacent to the south side. Fabre's real workroom was on the second floor of this wing. It is a room about fifteen by twenty feet with two small wooden shuttered windows on the east. In the middle of the room stands a long table on which repose some small wire insect cages, two or three glass jars and Fabre's only microscope of ancient pattern presented to him by the chemist, Dumas. At the farther end is a large fireplace, on the mantel of which stands the earthen tube and the egg of a burrowing beetle, *Geotrupes*, a tube of a cicada with its nymph, and a tube of a mining bee, all as Fabre had mounted them. Around two sides of the room, cases are arranged for holding his collections of plants, shells and insects. The main house has a wide hall running through the middle, with the dining-room on the left and the living-room at

THE STEPS LEADING UP TO THE POOL IN HIS HARMAS DIRECTLY IN FRONT OF HIS DOOR.

the right. About the walls of the latter are perhaps a dozen portraits of Fabre taken at different periods and at the farther end stands a large cabinet containing various editions of his "*Souvenirs Entomologiques*" while on the table in the middle of the room reposes the visitors' book containing the names of those who have called to pay homage to the scientist. It was the garden, however, that interested me most, for it was this part of the harmas that constituted the living laboratory of entomology in which so many of Fabre's observations on the behavior of insects were made.

The garden is cut off from the house and the wide way of which we have spoken by the water basins, the low stone wall with its cover of trailing vines, and the row of lilacs on the left border of the road leading to the iron gate. As we enter the garden through



BIRD'S-EYE VIEW OF THE HARMAS,

SHOWING THE HOUSE IN THE CORNER WITH THE WIDE WAY IN FRONT EXTENDING TO THE IRON GATEWAY; THE CIRCULAR POOL AND THE GARDEN WITH ITS TANGLES OF PLANTINGS ACCESSIBLE THROUGH THE WINDING PATHS.

the passageway in the wall we come first upon the fountain and its big circular pool among a thick growth of shrubs and trees through which the sunlight can scarce find an opening. Beyond the pool lies the garden proper in which Fabre planted and nurtured thick masses of the native herbs and shrubs with graveled walks threading their way through them and affording access to all parts of the lovely wilderness. He had simulated nature as far as possible in order to attract the insects he found among the native vegetation. Of the original fauna he says, "Never in my hunting memories have I seen so large a population at a single spot; all trades have made it their rallying-point. Here come hunters of every kind of game, builders in clay, weavers of cotton goods, collectors of pieces cut from a leaf or the petals of a flower, architects in pasteboard, plasterers mixing mortar, carpenters boring wood, miners digging underground galleries, workers handling goldbeater's skin and many more." It was here in the garden that we found a riot of golden broom, wild thyme, rosemary, purple sage, coronilla, honeysuckle, acacia, Judas-tree, lilacs, fig-trees and other wild native plants, many of them in bloom on this April day and flooding the air with their fragrance. The birds were busy with their spring nesting and were singing in the abandon of their joy, for the mistral had spent itself and the soft southern breezes were blowing across the garden, while the mountains, which Fabre loved so much, were of a misty blue in the hazy distance. This was where he made his "observations under the blue sky to the song of the cicada," where he studied "instinct in its loftier manifestations," and where he recorded "the habits, the manner of living, the work, the struggles, the propagation of that little world with which agriculture and philosophy

have most seriously to reckon''; and if he wished to vary his field of observation ''the mountain is but a few steps away, with its tangle of arbutus, rock-roses and arborescent heather; with its sandy spaces dear to the Bembeces; with its marly slopes exploited by different wasps and bees. And that is why, foreseeing these riches, I have abandoned the town for the village and come to Sérignan to weed my turnips and water my lettuces.''

The area enclosed within the walls of the harmas constitutes just about a hectare (2.47 acres), a comparatively small field laboratory, yet how productive it has been in the science of entomology. As I wandered along the paths through the garden where Fabre had walked and watched and recorded on many days as wonderful as this April day and beneath the marvelously blue sky of his beloved country I was filled with an overwhelming sense of gratitude to this man for the inspiration of his life, his work and the style with which he clothed his ideas. Of the latter he has been moved to say:

Others again have reproached me with my style, which has not the solemnity, nay, better, the dryness of the schools. They fear lest a page that is read without fatigue should not always be the expression of the truth. Were I to take their word for it, we are profound only on condition of being obscure. . . . Yes, my pages, though they bristle not with hollow formulas nor learned smatterings, are the exact narrative of facts observed, neither more nor less.

On my return from the garden, Mademoiselle led us into the living room in order that I might sign the visitors' book as the final act in our rite of respect to her father; but before taking final leave I requested the privilege of making a photograph of her to carry back with me to America. She seemed rather overcome with the idea of having her likeness exhibited among strangers so far from her home, but after some urging she shyly consented to stand and face the camera for a moment. The result, unfortunately, was not all I had hoped for, yet the film gave me a record more indelible and lasting than a mental one is likely to be. Much to my surprise and delight, when we finally arose to leave, she walked with us out through the tiny door in the wall and along the path outside of the harmas to the edge of the road; and the last picture I have of this memorable visit is that of the petite, wistful figure of Mademoiselle with her gray hair and wrinkled face standing by the roadside and watching us in an attitude of kindly farewell as we reluctantly started on our way back to the village.

DAVID RITTENHOUSE—PIONEER AMERICAN ASTRONOMER

By Professor W. CARL RUFUS
DETROIT OBSERVATORY

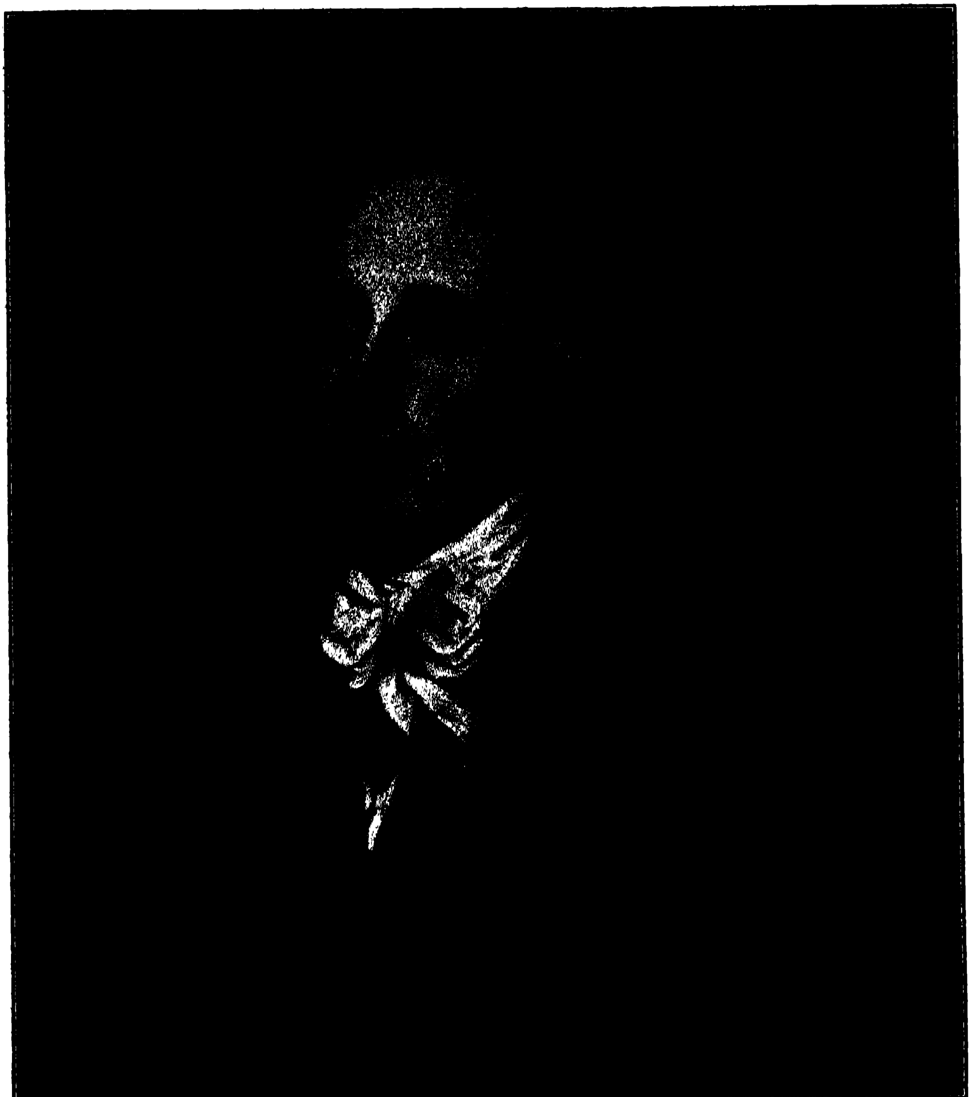
AMERICA'S preeminence in astronomy was not gained at a single bound. Pioneers during the colonial period and early days of the republic began the ladder from the lowly earth to the vaulted skies. Foremost among them were Benjamin Franklin, John Winthrop and David Rittenhouse, "the philosophical trio of the Revolution."

The genius of Franklin flashed in many fields like the lightning which he drew from the skies. Printer, author, organizer, scientist, philosopher and statesman, the many-sided Franklin dedicated to America a patriotic career in which the political scarcely outshone the scientific in his day. Original contributions to nineteen sciences are claimed for him, though modern experts dub him an amateur and a dabbler. Bridget, his wife, had little patience with his "rattle-traps used in astronomy." His Junto, 1727, was the precursor of the American Philosophical Society, of which he was the first president.

John Winthrop, of Harvard, led the first scientific expedition of this country to Newfoundland in 1761 to observe the transit of Venus over the sun. Heir to the riches of transplanted European scholarship, his broad culture and scientific research contributed largely to the reputation of Harvard, locally and abroad. His activities included observations of the transits of Venus and Mercury, solar and lunar eclipses, sunspots, meteors, comets, earthquakes, lightning, magnetism and aberration.

David Rittenhouse, son of the soil, was a self-made astronomer, a true product of American genius and toil and the highest embodiment of the pioneer spirit in science during the colonial period. On his farm in Norriton, Pennsylvania, with instruments of his own construction, he made observations of the transit of Venus in 1769 to determine the distance of the sun, which equalled in accuracy those obtained by professional astronomers, including the astronomer royal, fully equipped with the finest instruments of the world.

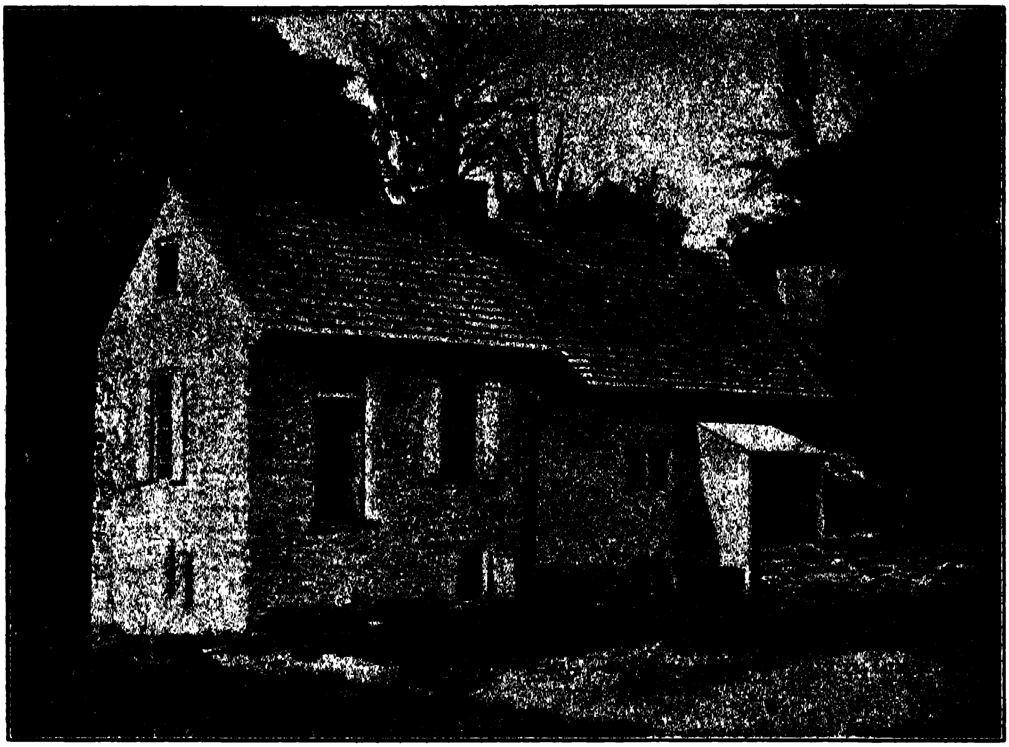
David Rittenhouse was born on April 8, 1732, the year of Washington's birth, at Paper Mill Run, near Germantown, Pennsylvania. His father abandoned paper-making, which was established in this country by his ancestors in 1690, and moved on a farm in Norriton, about twenty miles from Philadelphia. David, the oldest son, third child in a family of ten, at an early age was destined for farm work. His mechanical ability attracted attention by his boyhood productions, including a miniature waterwheel. This talent received encouragement at twelve, when he inherited a chest of carpenter's tools and mathematical books from his maternal uncle. No schooling beyond the three R's was available, but he assimilated all the books he could procure, showing special fondness for mathematics and astronomy and covering plow-handles, fences, stones and barn doors with figures and constellations. At seventeen he made a wooden clock, followed by a metallic timekeeper. His father reluctantly let him quit the plow, and at nineteen he opened a shop on the farm for clock-making, where he worked and studied assiduously, seri-



—*By Trumbull.* (*Loaned through the courtesy of the Pennsylvania Academy of Art.*)
DAVID RITTENHOUSE

ously impairing his health. He resorted to Yellow Springs for his health, but returned with a permanent pain in his breast.

Here alone he is said to have mastered Newton's "Principia" in the English translation of Mr. Motte. This classic contains the greatest contributions to science ever produced by one individual. The fundamental laws of motion, mass, force and acceleration were clearly demonstrated. Fluxions, a geometrical form of the infinitesimal calculus, were invented and used in astronomical problems. The law of gravitation, the greatest scientific generalization of the human mind at that time, if not for all time, was the crowning feature. The youthful



—*Courtesy of Popular Astronomy*

THE BIRTHPLACE OF DAVID RITTENHOUSE

genius recognized the superlative value of the masterpiece.

At this time, as frequently happens to developing genius, a fortunate incident occurred. Thomas Barton, an Episcopal clergyman educated at Dublin, came to America, taught in the Rittenhouse neighborhood, fell in love with David and married his sister, Esther. He was able to provide books and help direct the study of his protégé. Latin and Greek were attacked; the "Principia" was devoured in the original.

We next find Rittenhouse making a telescope. He wrote to Barton, who had moved to Philadelphia:

> I am spending my time in the old trifling manner, and am so taken with optics, that I do not know whether, if the enemy should invade this part of the country, as Archimedes was slain while making geometrical figures in the sand, so I should die making a telescope.

It is said that he constructed the first telescope made in America.

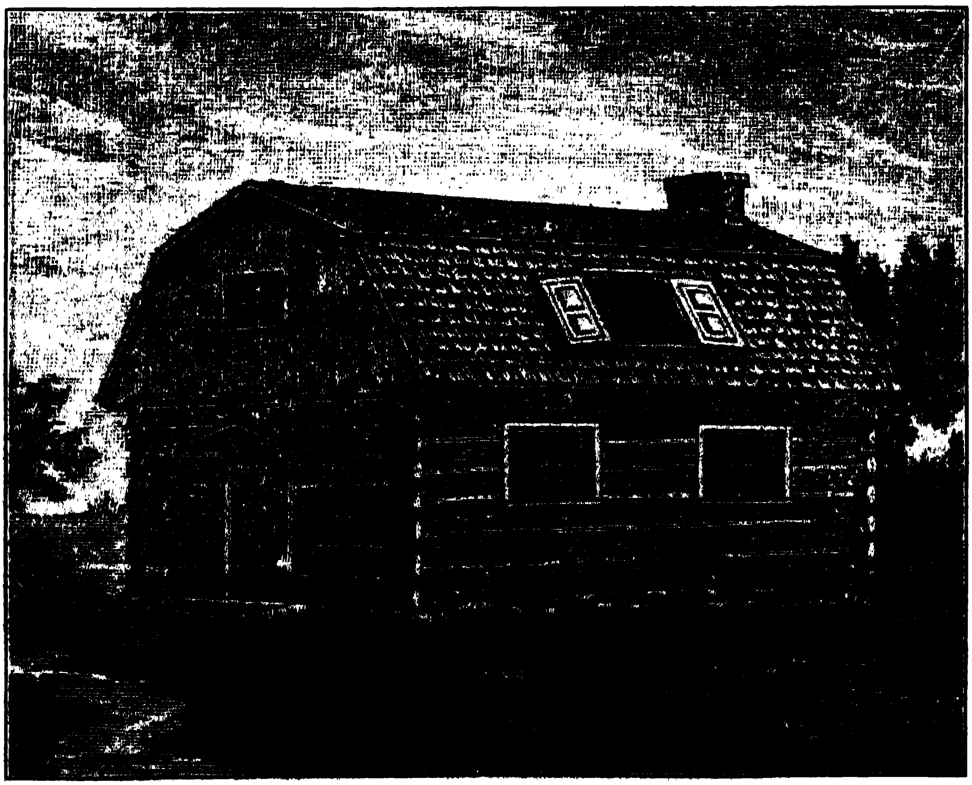
Through the influence of Barton his ability and skill were heralded in Philadelphia. Mr. Penn, proprietor of the province, engaged him in 1763 to "fix the circle about Newcastle" to settle a boundary dispute with Lord Baltimore. So accurate was the survey that Mason and Dixon, experts from England trained at the royal observatory, incorporated his work in their famous Dixie line. Later he settled numerous disputes involving Pennsylvania, Delaware, Maryland, Virginia, New York, New Jersey and Massachusetts. Part of his time was spent in making the instruments used.

In 1766 he married Eleanor Colston, a Quakeress, daughter of a neighboring farmer. Continuing the "old trifling

manner" of spending his time, he experimented on the compressibility of water, invented a metallic thermometer credited to Breguet in the nineteenth century, noted the effect of temperature on clock-rate and devised two kinds of compensating pendulums. He wrote a paper on the problem of Archimedes, concluding that without a lever a weight of 200 pounds applied for 105 years is sufficient to move the earth one inch. In 1767 the College of Philadelphia decorated him Master of Arts for "extraordinary progress and improvement made by a felicity of natural genius, in mechanics, mathematics, astronomy and other liberal arts and sciences, adorned by singular modesty and irreproachable morals." During the next three years two events chiefly engaged his attention, the construction of a celebrated orrery and the observation of the transit of Venus in 1769.

His first orrery, begun in 1767, was a complicated mechanism designed to illustrate the motions of the heavenly bodies. The problem of their motion had occupied the world's greatest thinkers for two thousand years. Plato set it for his disciples; Newton completed its solution by the application of his law of gravitation. Archimedes made a model to represent these motions; others had constructed larger and more intricate machines; but Rittenhouse proposed to transcend them all. He says:

I did not design a Machine, which should give the ignorant in astronomy a just view of



—*Courtesy of Popular Astronomy*

RITTENHOUSE OBSERVATORY

THE FIRST OBSERVATORY BUILT IN THE UNITED STATES.

THE FIRST KNOWN TELESCOPE CONSTRUCTED IN THE UNITED STATES, WAS MADE AND USED BY DAVID RITTENHOUSE. IT IS NOW ON EXHIBITION IN THE VERY ROOM IN WHICH RITTENHOUSE PRESIDED OVER THE MEETINGS OF THE AMERICAN PHILOSOPHICAL SOCIETY.

the Solar System; but rather astonish the skilful and curious examiner, by a most accurate correspondence between the situations and motions of our little representatives of the heavenly bodies, and the situations and motions of these bodies, themselves. I would have my Orrery really useful, by making it capable of informing us, truly, of the astronomical phenomena for any particular point of time; which, I do not find that any Orrery yet made, can do.

Here was an ambitious task! It required the accurate knowledge of the professional astronomer regarding the orbits of the planets and satellites and the technical skill of the trained mechanician to design and construct the combinations of wheels to guide the brass and ivory balls at their proper speeds, inclinations, nodes and eccentricities. All was to be driven by a pendulum clock contrived to play a variety of music. The main face was four feet square, of polished brass, silvered and painted and otherwise ornamented. In front moved the miniature planets around the sun with an accuracy sufficient to represent their positions for five thousand years. Two lesser faces were four feet by two feet three inches. One represented Jupiter and its satellites, their eclipses and transits; also Saturn with its ring and attendants. The other illustrated lunar and solar eclipses, including an optical device for exhibiting their appearance at any place on the earth.

A description of the orrery, communicated by Dr. Smith, provost of the College of Philadelphia, occupies first place in the first volume of the American Philosophical Society. Such was its fame in its day. Thomas Jefferson said of its maker, "He has not indeed made a world; but he has by imitation approached nearer its Maker than any man who has lived from the creation to this day." Princeton secured its possession, to the great chagrin of Dr. Smith. A second was made for Philadelphia. Negotiations for others followed. A trip to England for its exhibition was considered, but other events interfered including the transit of Venus, which had delayed its completion.

Transits of Venus occur in pairs eight years apart at intervals of more than a century: 1761 and 1769, 1874 and 1882; the next will be 2004 and 2012. Winthrop's trip in 1761 was mentioned; but no costly expedition for colonial astronomers in 1769 was necessary; the phenomenon came to their very windows. Rittenhouse's "Projection of the Transit" was laid before the American Philosophical Society. John Ewing presented one for Philadelphia. Three committees were appointed and three observing sites were selected, the State House Square in Philadelphia, the farm of Rittenhouse, and a station near Cape

Henlopen. Rittenhouse erected an observatory, designed not merely for this purpose, but for permanent use, the first built in this country.

The society lacked funds, and instruments were expensive. Politics helped to equip the State House station. It was "provided with an excellent sector of 6 feet radius, made by the accurate Mr. Bird, and an equal altitude and transit instrument, both belonging to the honourable Proprietaries of this province, which the Governor very generously lent to the society on this occasion." Telescopes and additional equipment for the State House Square were obtained from England. The farm did not fare as well. A Gregorian reflector with a Dolland micrometer was ordered from London to be used by Dr. Smith. With it came lenses for a refracting telescope for Harvard. Arriving too late to be forwarded before the great event, they were impressed into service, fitted together by Rittenhouse and used by Mr. Lukens. We hesitate to imagine the reactions of Winthrop, of Harvard.

Rittenhouse was left to his own resources. In preparation he made an equal altitude instrument, a transit telescope and an excellent timepiece, upon which depended the accuracy of the observations. He spent several months determining the latitude and longitude of the observatory, rating the clocks and making preliminary computations. Dr. Smith reported:

> Our other engagements did not permit Mr. Lukens or myself to pay much attention to the necessary preparations; but we knew that we had entrusted them to a gentleman on the spot, who had joined to a complete skill in mechanics, so extensive an astronomical and mathematical knowledge, that the use, management, and even the construction of the necessary apparatus, were perfectly familiar to him.

The success of the observations was due to Rittenhouse. Maskelyne, the astronomer royal of England, acknowledging their receipt from the Honorable Thomas Penn, says, "I thank you for the account of the Pennsylvania observations, which seem excellent and complete, and do honor to the gentlemen who made them." Rittenhouse immediately began the reductions. Data by the Norriton station combined with Greenwich observations gave the most accurate value of the sun's distance, 92,940,000 miles, in striking agreement with the present adopted value, 92,900,000.

Rittenhouse also observed an atmosphere of Venus, a phenomenon which escaped the astronomer royal. Other astronomical activity of Rittenhouse during this period included a transit of Mercury, November 9, 1769, a survey between the observatories of Norriton and Philadelphia, observations of Lexell's comet, 1770, and the determination of its orbit, "the fruit of three or four days labor." A paper on "An Easy Method of Deducing the Time of the Sun's Passing the Meridian" attracted the favorable attention of VonZach.

Fame was able to accomplish what patronage could not do. Rittenhouse was induced to move to Philadelphia in the fall of 1770. In December he suffered the loss of his wife, a severe blow to his sensitive nature. "Now, neither money nor reputation has any charms," he wrote to Barton. Work on his orreries and their explanation to crowds became irksome. The American Philosophical Society elected him as one of its secretaries; the Pennsylvania Assembly granted him an honorarium of three hundred pounds and bargained for a third orrery with a face eight feet square. Rittenhouse went so far afield as to prepare a paper, "Relating to Birds being Charmed by Snakes" and to carry on some experiments with Kinnersley on the electrical properties of the eel. In 1772 he was painted by Peale, honored by Princeton with the degree of master of arts, gave up a con-

templated visit to Europe and married Hannah Jacobs.

Commissions and offices were thrust upon him, some petty, others important. He served committees to examine specimens of flint glass, to tend rain-gauges, to examine the first steam-engine in this country, "which did not continue its motion long." He assumed charge of the State House clock, conducted boundary, canal and river surveys, became curator and librarian of the American Philosophical Society and delivered its annual oration on astronomy. He was about to become public astronomer with an observatory to be provided by the legislature, when suddenly the guns of Lexington and Concord were heard around the world.

Then followed the call to arms. Rittenhouse responded as engineer of the committee of safety for Philadelphia. To obtain lead for bullets he substituted iron for lead clock-weights throughout the city. He was called upon to arrange for casting cannon, to superintend the manufacture of saltpeter, to select a site for a powder-mill, to locate a magazine for military stores, to experiment on rifling cannon and musket balls and to devise chain protection for the harbors. He became vice-president of the committee of safety and president of the new council of safety, military executive of the state, which possessed unlimited capital power. At the approach of the enemy he issued an exhortation:

> We therefore entreat you by the most sacred of all bonds, the love of virtue, of liberty, of your country, to forget every distinction, and unite as one man in this time of extreme danger. Let us defend ourselves like men determined to be free.

As state treasurer he accompanied the removal of the capital to Lancaster. One week after the evacuation of Philadelphia by the British, Rittenhouse, Smith and Lukens returned to their telescopes to observe a solar eclipse, June 24, 1778. A pitiful effort had been made to maintain observations, including a transit of Mercury, November 2, 1776, and a solar eclipse January 9, 1777. Rittenhouse had also written a "Defense of the Newtonian System" in 1776 and in Lancaster prepared astronomical data for Father Abraham's Pocket Almanac.

The conflict between the demands of war and science was acute. The Declaration of Independence was proclaimed in Philadelphia from the platform of the transit observatory in State House Square. During the British occupation General Howe issued an order protecting the orrery of Rittenhouse. The one at Princeton suffered the loss of wheels and balls which adorned the watch-chains of colonial troops. Jefferson remonstrated against the transfer of the service of Rittenhouse from astronomy to politics. "Nobody," he said, "can conceive that nature ever intended to throw away a Newton upon the occupation of a crown." A well-meaning poet advised Rittenhouse:

> Meddle not with state affairs,
> Keep acquaintance with the stars.

Like Franklin, Washington, Jefferson and others, he responded unreservedly to the call of duty. He served on the Constitutional Convention of Pennsylvania and the General Assembly. He was state treasurer, trustee of the loan fund and member of the board of war. He was professor of astronomy in the College of Philadelphia, served on its board of trustees and filled the office of vice-provost. He was one of the commissioners to organize the United States bank and was the first director of the mint appointed by Washington.

But astronomy was his first love. In 1781, before the smoke of battle had cleared away, the assembly granted him 250 pounds for an observatory in Phila-

delphia. This he erected before providing a residence for himself and family. It was the only one in America recognized by the French astronomer, Lalande. To determine the meridian to adjust his instruments, when buildings interfered, he invented the collimating telescope, a substitute for a distant azimuth mark. This invention alone, so useful in practical astronomy, would assure its discoverer a permanent place in the history of astronomy. He also discovered the use of spider threads in the eyepiece of a transit; but this was anticipated by an Italian astronomer, Fontana.

When the American Philosophical Society resumed publication after the war, the contributions of Rittenhouse again formed an important part. These contained observations on the sun, moon, Mercury and the newly discovered planet, Uranus, on comets, including one discovered by himself, on a remarkable meteor and on the effects of lightning. He anticipated Brewster in explaining the apparent conversion of cameos into intaglios and *vice versa*, and solved an optical problem proposed by Professor Hopkinson. He conducted experiments on magnetism, the improvement of timepieces and the expansion of wood by heat. He invented a wooden hygrometer for measuring atmospheric moisture. His mathematical work included a method of finding the sum of several powers of the sines, another to determine the true place of a planet in an elliptical orbit, and a method of raising the common logarithm of any number immediately. Degrees were conferred upon him by American colleges; he was elected president of the American Philosophical Society and a foreign member of the Royal Society of London, the highest possible scientific honor of his day.

His lifelong association with Franklin resulted in mutual admiration and respect. He was one of the pallbearers of Franklin, whose will contained this item, "My reflecting telescope, I give to my friend, Mr. David Rittenhouse, for the use of his observatory." His friendship with Washington was also intimate. A painting of Rittenhouse hangs on the walls of Mt. Vernon. He made repairs and adjustments on Washington's surveying instruments, such as the theodolite. He made and presented a pair of spectacles to Washington, who donned them in public for the first time before his assembled soldiers with the pleasantry: "I have grown gray in your service, and now find myself growing blind."

Rittenhouse, too, was growing old and feeble. The troublesome pain had chiselled its way into the delicate, sensitive features. Peale, in his later paintings, only half conceals it. Trumbull caught the superfine spirit underneath. Rittenhouse mourned that he could not spend more time at his telescope. But the observatory claimed him at last. The end came rather suddenly; an attack of cholera, the doctor, the unsuccessful leech, the will and rest beneath the observatory.

They came to do him honor—Washington and his cabinet, congressmen, justices, foreign ministers, state officials and members of the learned societies. In their presence Dr. Benjamin Rush delivered "an eloquent, learned, comprehensive and just eulogium." Jefferson, succeeding to the office of president of the American Philosophical Society, paid this fitting tribute: "Genius, science, modesty, purity of morals, simplicity of manners, marked him as one of nature's best samples of the perfection she can cover under the human form." And to-day we add our token in memory of David Rittenhouse, America's peerless pioneer astronomer.

VISIONS AND DREAMS OF A SCIENTIFIC MAN[1]

By Dr. PAUL R. HEYL
BUREAU OF STANDARDS

VISIONS and dreams? Who is this speaking? A scientific man, you say? And pray what business has a scientific man with anything so beautiful, so fragile? Is not science matter-of-fact, gray and prosaic? And are not scientific men likewise, as every one knows? Visions and dreams of a scientific man, forsooth! What manner of dreams may these be? Fancy in a strait-jacket, for melody a monotone; but as for beauty—ah, how can that be?

Visions and dreams—man's most precious possessions! Was it not the greatest blessing which the prophet Joel could pronounce upon ancient Israel, "Your young men shall see visions, and your old men shall dream dreams"? But and if common opinion be true, then are we scientists of all men most miserable, for without dreams and phantasms can not a man live.

But common opinion is wrong in this matter. We scientific men have our share—ay, more than our share of these great gifts; the measure meted out to us is heaped up, pressed down and running over. And the visions and dreams of a scientific man are in no degree inferior to those of the mystic or the poet in grandeur or wonder, while they possess in addition a distinctive feature—a vitalizing element of reality.

Reality? What is real? We are not quite so sure of the answer to that question as we were thirty years ago, for the twentieth century has sadly turned our ideas upside down; matter itself has become a form of energy. The realities of to-day were the intangibles of the past generation; but intangible and immaterial as they may be they are none the less real.

Consider the compass needle quivering on its pivot. Hold a magnet toward it; see how it turns and points to the magnet, and how its quivering becomes more rapid. Bring the magnet nearer; the needle becomes still more excited. Does it not suggest a dog with wagging tail at the sight of food held out to him? He points always toward the food as we move it here and there, and the nearer we bring the food the more rapidly wags the tail. We can explain the phenomena exhibited by the dog, at least to our own satisfaction, for the dog can see the food; but what of the compass needle? Interpose a board between it and the magnet; the excitement is not one whit the less. What strange connection is there between the needle and the magnet? It is real, real as anything we know; witness its results; yet we can neither see nor feel it. And as we study this mystery and ponder over the reality of the intangible and the immaterial there wells up in us an emotion akin to that of that ancient mystic who, in the face of a great wonder, put his shoes off from his feet, for he felt that he stood on holy ground. Truly, the things that are seen are temporal, but the things that are not seen are eternal.

In the everyday work of a scientific man he is continually brought into contact at first hand with that which is wonderful and mysterious, and yet real. The simplest and most commonplace natural phenomenon, even the falling of a stone to earth, is wonderful past all speaking. This truth is for the most part obscured by familiarity. It is our task, as students and teachers of science, to brush away this dust of familiarity

[1] Publication approved by the director of the Bureau of Standards of the U. S. Department of Commerce.

and uncover the wonder and the mystery of that which lies below. And if, again, like Moses of old, we feel that we are slow of speech, let us call upon our blood-brothers the poets to speak in our stead; for the poets (may their tribe increase!) know well that science has its poetic side, and that scientific men also have their visions and dreams. They understand; and how beautifully they have expressed it for us! What does Longfellow say in his "Lines on the Fiftieth Birthday of Agassiz":

And Nature, the old Nurse, took
The child upon her knee,
Saying: "Here is a story book
Thy Father hath written for thee.

"Come, wander with me," she said,
Into regions yet untrod,
And read what is still unread
In the manuscripts of God."

And he wandered away and away
With Nature, the dear old Nurse,
Who sang to him, night and day,
The rhymes of the Universe.

And if ever the way seemed long,
Or his heart began to fail,
She would sing a more wonderful song,
Or tell a more marvellous tale.

Song and story, vision and dream—who can resist them? From old times these have been the surest way to the heart and the understanding of man. Nature's music is as potent as that of the Pied Piper; her tales lose no jot of interest because they are true. Truth is not only stranger but stronger than fiction. Men have died for truth, ay, even for that which they had been merely told was truth; and he who has once learned the language which Nature speaks asks for nothing better henceforth than to be her willing slave and devoted disciple.

And wherein lies this potency of Nature's appeal? What is the scientific man's reward for a lifetime of devotion? Very much the same as the reward of those who of old ate of the fruit of the tree of knowledge: their eyes were opened.

It is said that a lady once remarked to the artist Turner that she could not see in a real sunset the tints that he put into his paintings. "Madam," replied the artist, "do you not wish you could?" The scientific man pities him who walks unseeing and unknowing through the wonderland about him. To such a one is life truly gray, dusty, sordid and prosaic, not to the student of Nature.

The poet sees far, but the scientific man sees farther. When the aurora spreads its shifting tangle of white, green or purple across the northern sky your really prosaic person (whose name is legion) may be momentarily attracted by its beauty, but scarcely more than by the sheen of silk over a shop counter. The poet is more deeply moved, and speaks forth his fancy:

Upon the sky are blazoned forth
The silent fires of the North.

How rich the far horizon's glow!
What noble city lies below?

Methinks those gleams of pearly light
Reflections are from portals white;

That living green, from pastures blest,
Where weary souls for aye may rest.

And lo! 'mid other tints outpoured,
The royal purple of the Lord!

But the scientific man, as he looks at this flickering play of color, is conscious of a rush of visions through his mind, crowding upon one another. His thoughts go back to the sun, that great benefactor of our race, who besides feeding and warming us sets forth for our entertainment this gorgeous color symphony. He sees a storm arising suddenly in the solar atmosphere, some whirlwind great enough to engulf the earth, and toss it like a ball in a fountain; some "steep down gulf of liquid fire" (in Othello's phrase) which by magic transcending the swiftness of

Puck transmits its effect over millions of miles to the earth and excites this brilliant display for our wonder and admiration. And he sees more. He sees the compass needle forsaking its steadfast allegiance to the north in the vain attempt to follow this will-o'-the-wisp of the sky. He sees ships off their course unknowingly, perhaps dangerously. He sees disordered telegraph lines, anxious railroad officials, delayed trains and annoyed passengers, and there is borne in upon him an overwhelming sense of our utter dependence upon the sun, and of the bonds, intangible and immaterial, yet potent and masterful, by which the sun rules and sways his planetary family like some ancient patriarch whose word was life or death when he chose to speak it. He sees himself and his fellows as subjects or courtiers of this mighty sun-monarch, dependent upon his favor and his bounty for their very existence, and sensitive to the slightest change in his royal mood; and he reflects that, unlike mortal rulers, no flattery, supplication, gift or prayer can move by the slightest this monarch from his impersonal indifference, for he shineth on the evil and on the good, and sendeth rain on the just and on the unjust.

A word, to the scientific man, may be sufficient to call up a multitude of visions. Speak of time to the average person; it may connote to him the idea of something to be killed, to be gotten through with as pleasantly as possible; or to another something so filled with duties that he has no opportunity to think about it. To the scientific man it may suggest a portion of a thread that lies in his hand, which he may follow far back into the mists of antiquity, and see as he goes that most majestic of Nature's visions, the pageant of time.

Go back with the historian a few thousand years, until written records fail; then let the anthropologist lead you into the dark caves of the Pyrenees, and show you those wondrous wall paintings—older than Egypt, older than Babylon. Then stand with the geologist as he examines the fossil record of life on earth, millions of years before the advent of man; and when the geologist must stop for lack of material, study with the astronomer the genesis of our earth, of our solar system, as far as we can learn it by a study of the heavens.

What a vision have we here! What a pageant is spread before us as we follow back along the thread of time! At its beginning lies the sun, shining as now, but in lonely splendor, for no planetary system accompanies him. But see that other distant sun approaching! Will there be a collision? No; they will pass each other, and at a safe distance; but as they approach see how each sun, at the bidding of gravitation, raises a great tidal wave in the other. But the distance is too great to be spanned by these friendly efforts; a brief moment of closest approach, a supreme struggle to reach the other—and the outstretched arm of our sun snaps off, and breaks up like a water jet into a crowd of particles, large and small.

The visiting sun passes on his endless way; the pull of gravitation subsides, and our sun resumes his normal shape. But now he is no longer alone; the crowd of particles circles round him, gradually condensing into aggregates here and there, until it finally takes the shape of our planetary system, still retaining traces of its genesis in the asteroids and in the rings of Saturn.

And what of the other sun? Has he carried away with him a souvenir of his visit in the shape of a planetary system of his own? Perhaps; though if he were many times as massive as our sun he might have been able to retain his own mass while disrupting that of another.

A rare vision this, indeed; for so widely separated are the stars of heaven that such an encounter can not be expected to happen oftener than once in an eon. A planetary system such as ours must be an unusual thing in the uni-

verse; perhaps there may be but one other like it.

How profoundly a vision of this nature may influence our dreams! Who has not gazed at the starry heavens and speculated on the possibility of each of those distant suns possessing a planetary retinue? And it would be strange indeed if among those millions of planets there would not be at least a few hundreds in condition to maintain life. But how changed is our outlook! How infrequent a thing is a suitable setting for life; how rare and precious is that gift of life which we enjoy and in what low esteem do we often hold it!

But while we are philosophizing the pageant is passing. Look again—at the earth now. Its surface has cooled; land and water are to be seen there; but what a land it is! Barren rock, sand and gravel, desolate and forbidding, unrelieved by a single green blade or patch of soft brown earth. A desert prospect; yet strangely enough there is water in plenty—lakes of it, oceans of it! What curse lies on this land that it holds no living thing?

But look—there in that sheltered nook, where the water lies still—see that patch of green scum on the surface, and in the water a little slimy jelly here and there. Trifles? Ay, trifles as yet, but most wonderful, for in them lie the promise and potency of things incredible, which yet shall be; of grass, herb and tree which shall clothe the earth in green raiment; of fish and flying dragons; of mammoth, cave bear and saber-toothed tiger; and of man.

Feeble must have been life's first beginnings; many incipient sparks of life must have flickered fruitlessly out; but chance and a kindlier environment preserved others, and the flame grew, slowly at first, but with ever-increasing rapidity. And with the advent of man upon the scene the interest of the pageant for human observers becomes intense. This latter portion of the great drama of Nature may lack the grandeur of the first act, where the actors were suns, but what it lacks in mighty outline it makes up in a wealth of intricate detail.

Once there was a man favored of the gods, for he saw this act of the drama—saw it in a day dream which he was fortunately able to preserve before it faded away. It is long since this happened, before some of those who read these lines had discovered America,[2] and allowance must be made for theories now discarded, such as that the glacial period was caused by a change in the shape of the earth's orbit. But the pageant passes—let us look at this dream of a scientific man.

The Destroying Angel hovered near the earth. It was millions of years since he had last passed this way; space is large and his duties many. When the Destroyer had last seen the earth it had been a liquid, white-hot globe, just beginning to solidify, but now its crust had cooled greatly. Land and water divided the earth's surface between them, and on the land there were little creeping things.

"Ay," said the Destroyer, "It is time that I returned. Your time has come, ye maggots. I have seen your like before, on other balls, and I have done my duty."

Now the Destroyer was cunning and resourceful and cruel, so instead of crushing the creeping things he put forth his hand and gently pushed the rushing ball slightly out of its circular path. Round and round the sun it sped in an ever-lengthening ellipse, and with each year's circuit the winters grew longer and colder and the summers shorter. A great sheet of snow and ice began to grow about the North Pole, gradually covering the surface of the earth, and driving the creeping things southward before it, so that many of them perished from the cold. And the Destroyer left the creeping things to their fate, and flew onward, laughing.

[2] "The Destroyer" appeared in *Lippincott's Magazine* November, 1898.

But the push had not been great, and by the time the ice sheet had reached half way to the equator the elliptical path ceased to lengthen, and began gradually to reassume a circular form. And so it was, after some hundreds of thousands of years, when the Destroyer again passed that way, he found the earth's path again nearly circular, and the creeping things more numerous than before. The Destroyer's brow darkened, and he said: "This time shall ye all surely die!" But as he drew near to crush them he stayed his hand, for he saw strange sights, the like of which his eyes had never seen before. Tiny sparks glowed here and there; some of the creatures traversed the waters on floating things. On land, caravans were passing from spot to spot where the creatures were most thickly gathered. The Destroyer drew nearer and examined with interest. Here several of the creatures were gathered around one of the sparks beating something vigorously—clink! clink! Others were making long straight scratches in the soil with a crooked thing. But most wonderful of all, some were making black marks on sheets of white material, and others were gazing intently at similarly marked pieces.

The Destroyer withdrew his hand, saying: "Let be; let us see what will come of this wonder. Yet they shall know that I am the master, and that I can destroy them at what time I will." So saying, he stooped and breathed gently on a cluster of the creeping things. And so it was that when the creeping things felt the breath of the Destroyer they uttered piping little cries and drew shining things from their sides, and rushing forth to a neighboring spot slew many of the creatures there. Then came others to the rescue of those that were attacked, and still others to the support of those attacking until the fourth part of the world was at war. And again the Destroyer laughed as he flew away.

But a few thousand years after that the Destroyer again returned, and found the creeping things more numerous than before. Again he stooped and breathed upon a spot where the creatures were most thickly gathered; but now only a few drew their shining things, while from all the rest went up a hissing sound: "Sh—sh—sh—" until those who had drawn their shining things put them up again. And the Destroyer wondered greatly at the failure of this magic, but, being full of resource, he strewed seeds of pestilence among the creatures, so that many of them sickened and died. And there went up a wailing noise, and those that were left gathered together the bodies of the dead and dug great holes wherein they buried them by the hundreds. And again the Destroyer laughed as he sped onward.

But a hundred years after that the Destroyer returned and found the creatures more numerous than ever. They swarmed together in great clusters, where they did many marvelous things. Here one floated in the air, hanging to a little inflated bag, until the bag burst, and he fell to the ground and perished. At another place there was a great tube pointed upward, with a little creature looking through it. Again the Destroyer strewed seeds of pestilence among them, and waited with a cruel smile; but this time the seeds took no effect. Then was the Destroyer angered, and he said: "What, ye puny ones! Are ye mightier than I?" And stooping low, he blew a great wind upon the earth, so that many of the creeping things were swept to destruction. And when he rose he was red and panting, for it had taken much of his strength; so he flew away, but this time he laughed not.

In this vision there is clearly to be recognized a quality which we find often present in the visions of scientific men—a vein of tragedy. The beautiful aurora can not occur without bringing with it a measure of inconvenience and danger; and even the magnificent spectacle of

the starry heavens is not without its tragic element.

Of the vast collection of astronomical photographs at the Harvard Observatory only a fraction has as yet been examined; but the examination has gone far enough to bring out some rather startling facts concerning those bodies known as new stars or novas which appear every now and then. All of us have heard or read of them; some of us may have seen that brilliant one which appeared in Perseus over twenty-five years ago or that other which was visible about seventeen years later. A star previously unnoticed, of telescopic magnitude only, blazes up within a few hours to a brilliance perhaps exceeding Sirius or equal to Venus at her greatest brightness. Then it slowly fades away. Within the last thirty years one or two occurrences of this kind have happened with attendant phenomena which give us an idea of what may have taken place. The star, moving rapidly through space, as all stars do, including our sun, may have encountered something; perhaps one of those patches of dark nebulous matter with which space is strewn here and there, as dangerous as icebergs on steamship lines of travel.

Many of these dark patches can be recognized by their edges, sharply defined against the starry background surrounding them. If a star happens to plow its way through such a patch of material there will be temporarily a great increase in its surface temperature and a consequent disturbance of the star's internal economy, resulting possibly in an explosion. We are not clear as to just what happens, but from whatever cause the records of the Harvard Observatory show that it happens a good deal oftener than we have ever thought or like to think about. While it is not a matter of daily occurrence it does happen about once in every three weeks; fifteen times a year there is a nova of at least telescopic magnitude; fifteen hundred such occurrences in a century.

We do not need to go farther back than the period of recorded human history to reach a number of such catastrophes as great as the total number of visible stars. The conclusion, as stated by Professor Russell, is that on the average every star in the heavens must suffer this fate more than once in its lifetime!

Now life has been on this earth for at least a million centuries, and in that time there must have been a staggering number of such calamities; yet our sun has escaped. Did he suffer this fate before life appeared on the earth, or is his turn yet to come?

We do not know. There is nothing in sight to excite alarm. Our sun seems to be moving through an unusually dust-free region of space. Is it permissible for a scientific man to dream that the way has been swept for him?

The mind can not avoid speculating on what might have happened if only one of the many stars which have suffered this fate had a planetary retinue in attendance. What if there had been life on one of those planets?

It might have been. It may be happening somewhere at this moment, and the light-borne news may not reach us for a hundred years. Nature is icily indifferent to such a circumstance. It is of no moment whatever to her that there may be a planet attached to that sun which suffers his baptism of fire. There might even have been on such a planet sentient beings who lived and loved and liked life well, as we do. Perhaps some of them even "heard the glorious organ fill transept, loft and nave," and chanted exultingly: "In Thee have I trusted; let me never be confounded!"

Nature's visions are not all of green pastures and still waters. She does not always appear as the kindly old nurse with the story book. At times her aspect is that of a Gorgon, upon whom no man

can look and preserve his soul alive. He who aspires to be numbered among her disciples must be no weakling. He must feel the overmastering passion for truth, be the consequences to his philosophy what they may; truth above all things, even though (as Huxley says) "it sears the eyeballs." He must face the facts unflinchingly, and find the sanest, healthiest way of regarding them; and he must always remember that by his mental attitude, by his reaction to these visions, by the color which they impart to his philosophy, the great mass of unscientific people will judge of science itself, and approve or condemn it. *"Noblesse oblige."* We must set a good example.

This element of tragedy is but seldom found in the dreams of the mystic, who usually ignores or is ignorant of this aspect of Nature, and looks preferably on her more pleasant and subtly intoxicating side. It is perhaps more often found in the visions of the poet, though generally speaking the philosophy of the poet is, "It is so beautiful that it must be true." But the devoted student of Nature says: "It is so true that we must e'en forgive if it be not beautiful."

Such are the visions and dreams of a scientific man; beautiful at times beyond compare, wonderful and mysterious always, and often tinged with tragedy. This is what Nature has to offer her disciples, bitter and sweet together, as is life itself; and just as we find life worth living (else we would not be here to say it) so the student of Nature follows where she leads him, through fair and foul, up hill and down, by green pastures and through the valley of the shadow. Who knows most, fears least; and of the student of Nature, above all men else, it may most truly be said that he has eaten of the fruit of the tree of knowledge; that his eyes are opened; and that he is become as the gods, knowing the good and the evil.

Apart from the heaving, restless world
There lies the Land of Souls.
It hears no sound from the world around
As afar its tumult rolls.

The wall of the land has portals twain,
All beautiful to see.
The gate of life is of pearly grain
And Death is of ebony.

Sometimes the ebon gates swing wide,
And then a soul comes in,
All sore from strife in a long, long life,
And bruised and stained with sin.

Then virgin souls look pitying on,
And wonder what life may be,
And whether 'tis worth the pains of earth
To taste its mystery.

And once the gates of pearl fell back,
And a solemn voice was heard:
"Wilt thou have life, and test its strife?"
But not a virgin stirred.

Beyond the gate was darkness all;
Nothing might one descry.
Each shook the head in awful dread,
For each one feared to try.

Then forth there stepped a deep scarred soul,
Weary and sore and lame.
Not long before had it entered the door
Of Death, with the ebon frame.

About it still was the smell of life,
And still its breath came fast;
Yet through the gates where the darkness waits
It willingly, eagerly passed.

"Wilt thou have life?" Ay, give me life,
Bitter and sweet, O Lord!
Let me but sup another cup
Of thy precious gift outpoured!

Let virgin souls, afraid to pass,
Tremble before the door.
Lo, I have lived and drained my glass,
And fain would drink once more!

OPPORTUNITIES FOR RESEARCH IN MAMMALIAN GENETICS[1]

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I

FOR centuries man has been actively interested in observing, recording and interpreting the phenomena of heredity. Occasionally among the great mass of workers there have been individuals whose achievements have stood out in bold outlines differentiating them from their contemporaries, from those who had gone before, and from those who were to come. It will be necessary only to mention a few of the most distinguished of these to show the almost unbelievable development of our knowledge of genetics.

At the end of the nineteenth century scientists had accepted Darwin's demonstration of over-production, the existence of variation, natural selection, the elimination of the relatively unfit and the consequent survival of those better fitted to meet required conditions. At the same time many zoologists had begun to think in terms of soma and of germplasm, and had at least gone part way along the road of Weismann's theory of descent. Bateson's "Materials for the Study of Variation" had provided an excellent list of variations and Pearson's school of biometricians, to some extent encouraged by Galton's quantitative theory of inheritance, were busy investigating many problems of genetics in humans and in lower forms.

Then in 1900 came the rediscovery of mendelism. At the same period De Vries' theory of mutation provided a method for the origin of discontinuous variations. Within five years the reports of the Evolution Committee, and the work of Davenport, Castle and Cuénot showed that mendelism applied to mammals as well as to many other types. Various color patterns in mice, rats and guinea-pigs as well as hair length and form in the latter were among the first cases to be recorded. Within another five years, that is to say by 1910, many new types of genetic material among animals were being used and the star of *Drosophila melanogaster* had appeared above the horizon.

Three years later the first of Morgan's books on genetics had been published. "Heredity and Sex" outlined and described the occurrence of sex-linkage and the genetic significance of the sex chromosome along lines earlier hinted at by McClung and by Castle. Definite proof of the correlation between structures in the germ cell and the behavior in inheritance of certain characters had been provided and the hunt for new facts was on. The small size, rapid breeding and economy of Drosophila were supplemented by the establishment of its cytological picture, which in comparison with all other animals then being studied was relatively simple and suitable for analysis.

These facts bore fruit, and in 1915 Morgan and his associates published "The Mechanism of Mendelian Heredity." It included maps showing the linear order of genes within the chromosome and opened up a whole new vista of definiteness in our ideas of the structure of the germplasm. The gene moved rapidly into the good social standing and warmed the hearts of biologists who had long been no more than politely aware of

[1] The sixth annual Sigma Xi address, Nashville, Tennessee, December 27, 1927.

the terms "pangens," "ids," "idants" and "biogens."

With the publication of the "Physical Basis of Heredity" four years later, Drosophila showed itself to be a bonanza. Under the superlatively skillful hands and minds of Morgan and his group it had given to biologists four general principles to add to the two fundamental discoveries of Mendel.

Morgan lists the six principles as follows:

(1) Segregation
(2) Independent assortment
(3) Linkage
(4) Linear order of the genes
(5) Interference
(6) Limitation of linkage groups

Of these numbers one and two represent the discoveries of Mendel and the other four those of Morgan and his associates.

The physical basis of heredity had thus been placed on a basis of definiteness never before dreamed of; the accuracy of results based on experiments carefully planned and predicted in advance had proven amazing. A really great victory had been won and an epoch-making advance had been recorded.

And then a question formerly as cold and cynical as the attitude of a present-day fundamentalist became warm and took on a tone of far greater intensity of interest. Medical men, lawyers, sociologists, the clergy and educators began to ask "Of what value are these facts to man?"

II

Before that question can be answered let us see why man's attitude towards biology in general and his own in particular has changed and had led him to ask the question as he has. There is no doubt that medicine, law, sociology, theology and education have all of them become much more interested in and considerate of the findings and possibilities of research in human biology than they were one or five or ten years ago. Their changed attitude has undoubtedly been one of the chief causes of the shift in public interest.

Without taking too much time it may be possible briefly to review some of the factors which have contributed to the increased attention now being paid to human biology.

The medical profession taking advantage of greatly improved methods of hygiene and sanitation has developed the preventive phase of its activities very extensively during the past few years. Schools and programs of public health have grown rapidly both in number and in extent. Mass programs dealing with prophylaxis of various types were a common procedure during the late war. They, along with the peace-time programs of public health, have helped to create in the mind of the medical profession a sympathetic attitude towards the subordination of the selfish rights of the individual to the larger needs of the group as a whole.

To strengthen this movement additional impetus came from other directions as well. Among the most interesting of the tendencies which has rapidly been developing to a point of general influence is the emphasis placed upon psychoanalysis and upon the interrelation between glands of internal secretion and various psychoses. The public fancy has been caught and held by the spectacular advances of knowledge in this field. As a result the medical profession more than ever before has shown a willingness to turn its consideration to the general natural biological processes which provide defense against disease and which cause variation in the activity of the glands of internal secretion. These facts, coupled with the realization that psychological abnormalities in many cases trace back to physiological bases which are themselves a definite part of human biology, have helped to increase

still further such interest once it is aroused.

In a somewhat similar way sociologists, recovering from their first skepticism of any "law of inheritance," have noticed the temporary nature of changes induced solely by alteration of environment and the persistence of the variations produced by genetic change. The researches of Goddard on feeble-mindedness have been among the powerful agents in carrying conviction to the doubter. So also have been the numerous studies reported by Newman, Muller and others on identical twins brought up in very different environments.

Whenever the sociologist, wearied by the pressure of facts of genetics upon his environmentally inclined mind, has attempted recourse to the mossy bank of neo-lamarckism or to the bubbling Watsonian spring of behaviorism he has been prevented from enjoying uninterrupted rest by a nasty and almost continuous noise. This noise is the insistent voice of those all over our country who notice the rapidly rising cost in the care of mental and social defectives. It introduces a particularly blatant note in what might otherwise have become merely a mild academic and scientific discord characterized by *dyspepsia intellectualis*. The raucousness of the new voice is caused by the fact that it originates from the average non-scientific taxpayer from whose purse the hands of the legislature biennially, with as little pain as possible, removes the funds to support those institutions such as state prisons, homes for the feeble-minded, the insane, the paupers, the diseased, the blind, the deaf and the unattached old people. It is a voice which like the sword of Alexander cleaves the Gordian knot of scientific argumentation with a far from gentle insistence on the point that the supply of defectives of various sorts should be controlled and diminished by preventing their reproduction.

Following closely on the heels of this agitation and pouring through the breach thus made, believing that the limitation of production of crippled, diseased, feeble-minded, epileptic or otherwise obviously defective children is both humane and economical the advocates of the spread of contraceptive information for health reasons have aroused a great and growing interest in the betterment of the race and the protection of childhood by the scientific methods of human biological research.

This, in turn, has brought out the fact that certain social or religious groups believe in the production of the greatest possible number of children of all kinds, whether handicapped and sentenced to a life of idiocy and suffering or not.

A healthy deterrent for this point of view is to be found in the community fund method of supporting charities. Because of the impersonal and fair attitude of those obtaining and spending the public funds for charitable purposes under the community idea the groups or organizations engaged in encouraging the production of unwanted and unfortunate children will eventually be recognized and isolated. As soon as this is done the next obvious and unavoidable step will be to insist that those so engaged pay the full expenses of the individuals produced under their guidance who later become public charges of any sort. Not long after that action is taken economic need will do the rest. In view of all these facts and a score of others the consideration of which time does not allow, it is not hard to understand the interested attitude of sociologists.

The legal profession also has been able to utilize advances in genetic knowledge. Mendel's Law has helped in the determination of parenthood and by its definite findings in the case of the inheritance of certain types of feeble-mindedness has greatly aided the advances made in legislation governing sterilization.

The records and family history of criminals also show in many cases such obvious biological foundation for abnormal behavior that supporting evidence for sterilization, under certain conditions, has readily been obtained. The law as a profession is notably conservative, yet it has among its members a steadily increasing group of outstanding individuals who are interested in obtaining more information on the methods of genetics to serve as the basis for constructive legislation.

The clergy has also become intensely aware of human biology.

Change in social attitudes may mean reform and reform in turn may mean discomfort to the existing stability of a ruling group. It is not surprising, therefore, to find one group of fundamentalist and conservative members of the clergy holding up as examples of filth and vileness those who are interested in the study of mankind from a biological point of view. On the other hand, the progressive members of the clergy are among the most ardent and alert followers of experimental science. Once these men realize that the acceptance of new truths does not mean loss of caste, they frequently become sufficiently radical to cause some embarrassment even to the most advanced of the experimental scientists themselves.

It is a healthy thing, however, to find such an active interest among the clergy and to see that many of them realize that the fate of international cooperation and of the world peace that would ensue depends very largely upon the characteristics of races and nations. These characteristics are many of them hereditary and so are biological in the most definite sense. Acceptance of this fact has done much to increase reliance in genetic differences and in the research which deals with them.

Educators also are peculiarly aware of the need for more accurate knowledge of the biological nature of the individual.

The great increase in our population has brought with it, quite naturally, an increase in the number of school children. The congestion resulting from this fact has spread from the lower grades of elementary school through all the higher levels to include even graduate or professional work. Selection in increasingly intelligent and strict form has been necessary because higher education is expensive and could not be distributed broadcast to any and every one who merely indicated their wish to receive it.

This has set educators to work in an attempt to develop a wiser and more honest method of rating mental ability than had formerly been in use. Such action was necessary if wise selection was to be practiced. Various mental tests have shown that mental ability is to a considerable degree definite, measurable and analyzable. They have also shown beyond any doubt that differences both in type of mental ability and in extent of general mental development are present in very young children. As a result, preschool units have been greatly developed. Child-study even with infants has become increasingly emphasized and will undoubtedly grow to even far more extensive proportions. No more impressive demonstration of the genetic and biological basis for individual differences in man could be obtained than are facts derived from such study.

The possibility that we may some day be able to predict achievement in the early years and so prevent waste of promising human material has come to the front with greater vigor and more hope than ever. As a result the mind of the educator is open to-day as never before to a sympathetic consideration of and interest in genetic research.

By very different but by converging roads the alert progressive phases of medicine, sociology, law, theology and education have thus met to combine in asking the laboratory geneticist the ques-

tion already referred to, namely, "Of what value to humanity are all your findings?"

III

It is very evident even from the very imperfect statement of the situation just made that there is a wide and somewhat awesome gap between the details of the structure of the germ cell in Drosophila and the wise direction of a program of improvement in human biology.

Jennings in his recent address as retiring president of the American Society of Zoologists expressed most intelligently, and to me most convincingly, the dangers and difficulties of applying in detail the conclusions drawn from results obtained in the study of the genetics of one form to the untried performances of another unrelated type of organism.

I shall not attempt here a comparison between the obviously widely divergent fields of plant and animal genetics but merely indicate a few of the differences which appear to me to be critical and unsurmountable barriers in the road of interpreting the detailed genetic problems of man on the basis of work, no matter how skilful, done with Drosophila or other insects.

The object in doing this is in no way a desire to discredit the splendid work done in the field of insect genetics. It is merely an attempt to show that the gap between the laboratory phase of experimental genetics and the interest in human biology will not be bridged by research in forms as widely separated from man as are the insects.

The insect is remarkably definite and fixed in a biological sense. From the very egg—itself more or less definitely organized into zones or regions—it shows a tendency to specialize its structures for detailed and well-defined objectives. The segmental arrangement of antennae, body and legs is further evidence of detailed morphological differentiation. The compound eye is a sort of declaration of morphological policy which is characteristic of insects.

The normal physiological responses of insects are also very detailed and definite. The freedom of secondary sex characters from the influence of secretions of the gonad is a typical example of the independence of organs and tissues which exists in insects. The phenomenon of a complete metamorphosis is also an indication of the discontinuity and highly evolved organization of the developmental process in insects.

The vast number of instinctive responses in insects shows that their psychology shares to a high degree the particulate and mosaic type of constitution that applies to their physiology and morphology as well.

It seems quite natural then to find that in most of those insects already studied the germ cells are highly definite and regularly organized. One would expect nothing else if the germ cell is to be considered a characteristic part of the individual and a reasonable precursor to the organism arising from it.

Man lacks much of this definiteness. Beginning with an egg that appears to be more completely interdependent in its various parts than is that of insects he develops during his embryonic life in a carefully controlled environment. Constant internal temperature, moisture and food conditions allow the free development of a balanced and elastic type of organism.

Interchangeability of body fluids, dependence of form, rate and extent of growth and maturity upon internal secretions—and relative elasticity and indefiniteness of mental processes all are directly in contradistinction to the conditions found in insects.

It would not be at all surprising if in mammals the internal organization of the germ cell itself, including the interrelationships between cytoplasm and chromosomes and between chromosomes

themselves, was much less definite and predictable than is that of insects. In fact a recent paper by Miss Swezy in *Science* showing that the ordinary white rat may have either forty-two or sixty-two chromosomes without marked morphological change seems to prove that in one case at least such is the case.

It is true that there are chromosomes in insects and in mammals and that there is likewise evidence for mendelian inheritance in both forms. To draw close homology, or even analogy, however, between the detailed genetics of man and of insects would be exceeding our present knowledge. There is a real gap between the two forms.

There is, however, already in position the foundation of the main support of the bridge over the gap referred to. It has not yet been built high enough for a level and comfortable transition, but it has definite possibilities and as I see it must be constructed before we can expect much real progress in human biology. The structure to which I refer is the steadily growing mass of information being obtained in the field of research in the genetics of the laboratory mammals.

IV

To collect data which will help to bridge the gap we must observe certain general rules of experimental procedure. First, the problems to be investigated must be of interest to man. One can not expect by mammalian genetics to extend the influence of or deepen interest in human biology unless the problems investigated have some connection with those of the larger human field. Fortunately, the great majority of problems which are capable of study in the laboratory mammals are of just that sort—as I shall try presently to show.

It is also necessary that the problems connect with known genetic phenomena; that they trace back to some sort of relationship with research in genetics of lower animals or plants. Unless this is the case the benefits of the general principles and fundamental values of the relation between biology and its more exact sister sciences, physics and chemistry, are apt to be lost sight of. The bridge, in other words, if it is to function properly, must have well-developed approaches from both sides.

Besides being of interest and value to humans and being based on sound genetic theory the problems must be capable of investigation in economic and suitable material. The last requirement is, of course, purely practical, but for the purposes of successful experimental procedure it is essential. Among mammalian material the types which are favored for experimental work are at present practically entirely confined to two carnivors and four types of rodents.

Cats offer interesting color differences, certain structural variation such as short tail and polydactylism, variation in length of hair and the best case of sex linkage known in laboratory mammals. For breeding purposes in great numbers, however, they are a bit too non-social and are subject to epidemics.

Dogs have a great wealth of color, varieties and of morphological, physiological and psychological differences. In these respects and in their small number of chromosomes they are unique among laboratory mammals. They are slow-breeding and expensive to raise, but they will undoubtedly eventually be used on a large scale.

Among rodents, rabbits are the largest and slowest breeding of those used. They have a few genetic morphological variations but a good list of color differences and between some varieties marked difference in size. They have also a good reputation as material for experimental medicine and are valuable for serological experiments.

Guinea-pigs (in spite of excellent press agent work by Ellis Parker Butler) are not very rapid breeders. Their morphological variations are almost as

scarce as rabbits and their average number of young per litter (between two and three) is very small. Their number of color varieties and their chromosome conditions are not radically different from those of rabbits.

Two types of rats provide distinctly better material than either of the foregoing. With a fair number of color varieties they combine a high degree of fertility and relatively rapid rate of maturity. Their size makes them economical of space and convenient for most forms of operative technique. Mice of two genera (*Mus* and *Peromyscus*) appear, however, to be even better material than is any one of the other types. Only slightly inferior to rats in respect to litter size they have many more color varieties, more morphological types, far greater size differences and a number of distinctive physiological characters. Three available species of the genus *Mus* afford an excellent chance for the study of hybridization and its accompanying phenomena. The mechanical advantages of mice are also great. They are only about one fifth as large as rats and therefore are much more economical of food and space. They mature much more rapidly and provide embryos of convenient size for histological study and sectioning *in toto*. In my opinion they offer the best material for experimental genetic work with mammals.

With this brief review of the qualities of different types of available material let us consider the fields of research, particularly of interest to mammal geneticists.

V

There are at least five great groups of genetic problems which are capable of successful investigation in laboratory mammals and which fulfil all conditions outlined above, being of interest to man and in close contact with other fields of experimental genetics. These problems include the genetic bases for size and growth, fertility and sterility, susceptibility or resistance to disease; lethal action of genes during development and psychological differences.

Although there will be undoubtedly interrelation between the five fields they will each be able to provide ample chance for fundamental and continuous research. Let us review each of them briefly.

(a) Size and Growth

Investigations by Sollas reported soon after the rediscovery of mendelism showed that dwarfism in guinea-pigs was inherited as a recessive, in some way related to sex. Castle showed that ear length in rabbits was inherited but by no simple method; MacDowell carried the problem farther in a detailed study of body weight and skeletal measurements in rabbits, Wright and Castle both contributed to the discussion of the nature of the genetic factors involved. Detlefsen, in recording a cross producing hybrids between the common guinea-pig and a related wild species, showed the relation of the growth rates of the three types. The two greatest opportunities for the study of size inheritance in mammals are however as yet practically or entirely undeveloped. Dogs, in which artificial insemination is possible and where body weight is fifty times or more as great in such a variety as St. Bernards as it is in chihuahuas, are splendidly fitted for use in investigations of size inheritance.

A cross between *Mus musculus* and *Mus wagneri* would also provide excellent material. The size difference is striking. It would be easy to back-cross the hybrids with either parent and to save the skulls and long bones of thousands of animals in each generation. There are enough color genes already described in *Mus musculus* to run a good chance of finding any existing linkage between genes for color and those for size.

In addition to factors involving general size and growth there have been several cases of localized growth phenomena which have been investigated. The inheritance of short tail in mice, dogs and cats has been shown in each case to be a mendelian dominant over normal tail length. Polydactylism in guinea-pigs and cats is dominant, while when associated with other digital abnormalities in mice it is recessive and influenced by modifying genes; an abnormal jaw and buccal cavity in mice is also recessive and lethal. Uncontrolled or abnormal growth of certain teeth in rats seems to occur in families, although its method of inheritance is not as yet clear.

The great morphological variations in dogs have provided and will continue to offer a splendid field for study. The shortened and crooked legs of the dachshund and the curled tail of the chow have proven to be mendelian dominants. Recently, recognizing the great value of dogs as genetic material, Stockard has started a series of experiments to determine the relation of morphology to glands of internal secretion. The results will be awaited with great interest.

The work of Davenport on the inheritance of stature and that of other investigators on different forms of dwarfism in man show that such comparative studies would be valuable. The genetic importance of different local variations in morphology are also well known in man. Polydactylism and brachydactylism are inherited, and the latter may possibly be lethal if present in a homozygous condition according to the work of Mohr—there is ample evidence that the study of these problems in laboratory mammals would have a direct interest for human biology.

(b) Fertility and Sterility

Differential fecundity and fertility in man lie at the foundation of the relative rate of increase of different nationalities and social groups. Laboratory mammals are well adapted for study in this general field.

The opportunity to make specific crosses is excellent. Detlefsen found a most interesting case of partial sterility related to sex in hybrids of *Cavia rufescens* and *C. porcellus*. Several investigators have found diminished fertility among F^2 and subsequent hybrid generations in a cross between Japanese waltzing mice (supposed to be derived from *M. wagneri*) and common mice (*M. musculus*). Crosses between *M. musculus* and *M. wagneri* and *M. musculus* and *M. faeroensis* have recently been made and will be available for further study.

A more accurate measure than ever before of fertility of female mice is provided by the technique developed by MacDowell which enables us to count the actual number of eggs liberated at any ovulation. Among dogs the average litter size of such breeds as airedales is very high, probably in the neighborhood of nine, while the greatest number in such breeds as chihuahuas is two or three, thus providing a splendid chance to determine whether the difference is inherited. Injections of extract of the pituitary has been shown by P. E. Smith to result, in mice, in greatly increased numbers of eggs at any one ovulation in mice. As many as twenty-nine implanted embryos have been counted in a single pregnancy by Smith, although the largest litter record at birth among the tens of thousands of cases in our laboratory is fourteen. By this technique we can evidently introduce an interesting experimental factor. In addition to this the effects of temporary sterilization induced by X-rays or other means is open to study. It is a well-recognized and easily obtained phenomenon.

Although these things are apparently disconnected, they all have a direct bearing on human genetics. So also have

the numerous investigations made on the effects of reproductive overwork, the relation of nutrition to fertility and the effects of these various things on the course of the oestrus cycle.

The possibility of controlling the sex ratio by altering experimentally the body fluids of the female reproductive tract, the modification of the sex ratio by other agents such as X-rays, hybridization or artificial insemination with sperm of different ages are also matters for study in laboratory mammal material, which is rich in its opportunities in these and in allied fields.

(c) Susceptibility or Resistance to Disease

There are two general types of pathological conditions which will be open to investigation in laboratory mammals. The first of these deals with infectious diseases.

Wright has shown that inbred strains of guinea-pigs may differ from one another in respect to their susceptibility to tuberculosis. Hagedoorn has published evidence which he believes demonstrates hereditary differences in susceptibility to an intestinal infection in hybrids of waltzing and tame mice. Tyzzer has described a microorganism which lives within the cells of the liver and causes death to Japanese waltzing mice but not to ordinary non-waltzing varieties. There is undoubtedly a great field for research in this general line of work. Slye has frequently shown clearly that there are particular strains and families of mice in which death due to infection of various types is much more common than in others—thus suggesting hereditary differences in this respect.

A second type of pathological condition resulting in structural or functional defects is known to be genetic in several cases. Cole has described the inheritance of paralysis agitans in guinea-pigs as a mendelian recessive. Stockard and Papanicolaou found a number of cases of disequilibration and nervous tremor in successive generations of guinea-pigs, following treatment of the ancestral generation with alcohol fumes. Przibram found hereditary deafness common in blue-eyed white cats, and Yerkes found that after the sixteenth day all waltzing mice are deaf. In this case waltzing and its accompanying deafness are inherited together as different manifestations of the same mendelian recessive. Keeler has recently described a rodless condition in the retina of certain albino mice. Here also a simple recessive character is involved. Jones has obtained in experimental animals a strain of rats in which reduction of one or both eyes is inherited but not in a simple mendelian fashion. In the descendants of X-rayed mice Bagg and the writer have described inherited eye and foot abnormalities and Bagg has recorded absence or reduction of one or both kidneys, which is also inherited.

In man there is a whole series of structural or functional diseases which are inherited. Hemophilia, nystagmus, hypospadias, Huntington's chorea, diabetes insipidus, xeroderma pigmentosa and alkaptonuria are examples chosen at random to show a wide range of characters which may be affected.

In addition to the conditions already mentioned the hereditary tendency to form mammary and other forms of cancer has been investigated. A number of investigators, Tyzzer, Strong, Haaland, Loeb and Lathrop, Slye, Lynch, W. S. Murray and the writer have published a considerable body of papers in the general field of genetics of cancer. At present it seems as though in mice mammary cancer behaves as a mendelian dominant, the manifestation of which is limited normally to the female sex. Slye's work shows also that different families or strains may be developed in which the particular localized types of tumors are relatively constant for any particular group. Many of the types

other than mammary cancer are in no way sex-limited. The evidence for the exact method of inheritance of the tendency to cancer in man is naturally not so direct or so easy to accumulate. There is no reason at present, however, to lead one to believe that the conditions in man are widely different from those described in mice. It can easily be seen that the genetics of comparative pathology will be one of the most important divisions of the general field of mammalian genetics as future developments are recorded.

(d) Lethal Action of the Gene During Development

Lethal action of a mendelian gene in animals was first discovered in mice. Embryological research by Kirkham, Ibsen and others established the correctness of an hypothesis based on experimental genetics on the inheritance of dominant yellow coat color in mice. The hypothesis advanced by the writer and Castle (1910) was that homozygous yellow mice started but did not complete their embryonic development. Such being the case it follows that an excellent chance for investigating the nature of lethal factors is offered.

In mice also a dominant type of spotting, producing when in combination with the ordinary piebald spotting a variety known as "black-eyed white," also acts as a lethal independent of yellow coat color. Detlefsen and others have recorded the appearance at birth and the survival for a few days thereafter of a pale whitish anemic type of young. This they have described as being the homozygous black-eyed white. It may be that such is the case. The writer, however, has found what appear to be similar young in the cross of black-eyed white by piebald from the same stock. Since all black-eyed whites in that case are heterozygous it would not be possible for homozygosity of the factor for dominant spotting to have caused the lethal action. Wriet has described a dominant spotting in merle "dunkerhunds" which causes death if present in a homozygous form. The short-tailed variation in mice is also described by Nageli as a clear case of dominant lethal. Mohr, as it has been stated above, has published some evidence that brachyphalangy in man acts like a lethal. The writer and Gibbons have tried to show by a statistical analysis of human pedigrees of hemophilia and color blindness that there were certain physiological factors at present unidentified but lethal when present in any situation unbalanced by a normal gene. In the cases recorded they chanced to be sex-linked and therefore distorted the sex ratio so clearly as to be recordable statistically.

The relation of lethal factors to the occurrence of still-births in man is a matter for attention and research. It should prove to be a fruitful and interesting field of cooperative endeavor between mammal geneticists and the medical profession. Data obtained from the Sloane Maternity Hospital in New York showed that there are fewer still-births when the parents are from different nationalities than when they are of the same. Whether this means that the embryo in a relatively inbred race was not able to survive and that the embryo derived from a cross between nations showed heterosis or hybrid vigor and so survived is not known but should be further investigated.

Lethal genes are interesting not merely because they may account for considerable lowered fecundity through early mortality but also because in studying the process of disintegration of the embryos killed by lethals we may be able to get a better idea of the nature of growth, morphogenesis and of the development of the gene's activity at different stages in ontogeny.

(e) Psychological Factors

The evidence of inheritance of general mental ability in man is strong

enough to be an impetus to further research. From Galton's study of men of genius to Wood's more recent investigation of the same general topic and Banker's research on families of Harvard alumni a mass of facts has been piling up to show the hereditary basis for ability.

Special abilities also give evidence of a genetic foundation. The work of Stanton, Seashore and others in the analysis of musical ability and in tracing the inheritance of its various component parts sets a standard for this type of investigation.

The field of genetics of psychological characters in laboratory mammals is almost a new one. The relation of habit formation, associative response, learning, memory and other psychological phenomena to various genetic phenomena, such as inbreeding, hybridization, overcrowding, isolation, malnutrition, and to the activity of the glands of internal secretion will offer important fields of research for decades to come. Bagg and Vicari have already independently shown differences in rate of learning between inbred strains of mice and the latter has demonstrated an effect of heterozygosis following hybridization of two such strains. MacDougal believes that he has evidence of the inheritance of an acquired habit or ability in rats. Pavlow has described experiments with mice in which he attempts to prove that the effects of learning are inherited. His work has been repeated with negative results by other investigators and might well have followed rather than preceded a careful and extensive study of the normal racial and individual variation in the process of learning in mice.

Dogs will also provide admirable material for the study of the genetics of psychological phenomena. Habits, such as "pointing," "setting," "springing," "giving-tongue," "going to earth" and a number of other natural responses, can be studied and compared with the great number of types of habits following training that will bring out marked individual differences in ability.

Both dogs and mice have enough physiological and morphological variations to provide an excellent opportunity for the investigation of linkage between psychological and physical characteristics. Possibly from such research will come more definite and extensive knowledge of the nature of many of the fundamental mental processes.

The importance of such investigation to education is very evident and when generally recognized is certain to mean increased experimentation and cooperative research between schools of education and departments of mammalian genetics.

The necessarily imperfect and hurried survey of five broad fields of possible investigation can now be considered from the point of view of four great general unanswered problems. These are the permanency of genes, the relation of soma to germ plasm, the nature of the gene as shown by its activity during ontogeny, and the possibility of producing genetic change by gradual action of various substances.

(1) The Permanency of Genes

The recent work of Muller has shown that in Drosophila the rate of genetic change by mutation is very rapid. So high is it, in fact, that the usefulness, in that material, of the pure line hypothesis of Johannsen, and the genetic fixity and relative unity of inbred lines seem very much in doubt. It may prove a great handicap to future research to have a form so subject to mutation that its stability, when desired for testing purposes, is not reliable.

It will at all events be desirable to investigate, in addition, such forms as mammals, in which the rate of mutation at various ages and under different types of physiological or other environment can be observed. We know from

the work of Strong and the writer that in mice the normal and characteristic development of the individual proceeds from an initial phase of relative undifferentiation to the peak of physiological individuality at the young adult stage of the individual. As the animal approaches senility there appears to be evidence that its degree of individual differentiation again decreases and that this condition continues until the death of the animal. Senility thus at least superficially resembles a physiological "second childhood."

If now, as the work of P. E. Smith shows, it is possible to bring on the process of ovulation at an earlier than normal age by injections of anterior lobe of the pituitary, we shall be able to increase the scope of our field of experimentation. It may also be possible to prolong ovulation in mice which in other respects are approaching senility by the same method or by some other type of rejuvenation process. This will enable us to study rate of mutation under varied internal environments. Quite as good a chance of studying the permanency of genes is afforded in males of different ages.

The effects of changes in the gene would, of course, be measurable in respect to rate of maturity, degree of fertility, length of life, rate of growth, susceptibility to disease and a number of other processes which are very difficult to study experimentally in animals with too short a life span. The additional fact that transplantation of various normal and neoplastic tissues in mice have given us a means of analyzing the genetic nature of many physiological processes is a further indication that variations by mutations other than those of form or structure will be more easy to detect in these animals than they would in forms where transplantation is not so easy.

(2) Relation of Soma to Germ-plasm

The classic experiment of Castle and Phillips in which black young were obtained from eggs derived from ovaries of a black female guinea-pig transplanted to the body of a white female gives clear indication of the opportunity which exists in mammals for research on the relation of soma to germplasm.

While the particular characters used by Castle and Phillips as tests of whether an influence of the foster-mother could be detected were not ideal, there are many others which can give us information of a more accurate nature. The use of a color character of the type involved in the difference between colored and albino animals is not as well calculated to demonstrate minor degrees of modification as would be a test involving such differences as those of spotted animals as contrasted with solid colored ones, or of the more subtle physiological characters, such as susceptibility to transplanted tumor or inherited differences in size. In these cases, as well as in psychological traits, it is easier to detect the minute quantitative variations or modifications which are not so readily detected in the case of color characters of the sorts used by the investigators referred to.

To provide an additional field of research, the possibility of regeneration of ovarian tissue in mice, recently described by Davenport, suggests that a new line of approach to both changes in mutation rate and in the relationship of germ-plasm to soma may be developed.

The techniques of MacDowell and of Nicholas show that we may, with care, expect to develop methods by which we can obtain more accurate first-hand knowledge of what is going on during the stages of ovulation, fertilization and embryonic development. This should aid greatly in solving certain of the problems of relationship between maternal and embryonic tissue, and so contribute directly to the general question of the inter-relationship of soma and germplasm.

(3) The Production of Genetic Change by Gradual Treatment

Mammals are peculiarly fitted for experiments in this general field. Besides providing us with a wealth of different types of characters to be studied, time is afforded during the various stages of the development of the individual so that we may analyze with considerable accuracy both experimental treatment and its effect.

Stockard and Papanicolaou's work in guinea pigs with alcohol fumes, and Guyer and Smith's experiments with rabbit lens antibodies are two well-recognized cases in point. In addition, Bagg and the writer have reported morphological genetic variations in the descendants of X-rayed mice, and J. M. Murray has published a preliminary note on some of the direct effects of irradiation. Jones has cooled and dried the Fallopian tubes and uterus of rats of the selected inbred Wistar Line "A" strain in the early stages of pregnancy. Certain of the young derived from implantation following this treatment had defective eyes. The defect appears to have been inherited. Numerous investigators have shown direct effects on growth, size and fertility by dietary changes; and Johnson (unpublished work) has found changes in the same direction by repeated exposure of young mice to ultraviolet light. These investigations suggest that repeated treatment by any or all of these means can be made a method of testing whether germinal change can be induced by gradual modification of environment. Mice which commonly give four generations per year and yet have an individual life span of two years or over are ideal for work of this type.

The possibility of the transmission of immunity slowly acquired is also worth careful study and is capable of much more interesting analysis than has yet been given it.

By using these and other methods the old but always interesting question of "use and disuse," if taken in its broadest meaning, will, in laboratory mammals of known genetic types, be capable of new and more important investigation under experimentally changed environments.

(4) The Behavior of the Gene during Ontogeny

After the gene has been located and the chromosome mapped with great accuracy, we shall still need to know all that we can concerning the gene as an activator, deterrent, inhibitor or other influence on structure and function during ontogeny.

We can not avoid the fact that until it is translated into terms of activity the gene will remain an inert locus in the gamete and will not be analyzable or even describable in any significant terms. It is not at all necessary to subscribe to the old fixed correspondence between gene and character which lay at the basis of much misunderstanding and discussion, following the earlier work of Cuénot and of Castle. One may cheerfully admit that many genes influence the appearance of every character and take part in its development, or that any gene may influence many or all characters of an individual organism. One may also willingly agree that the gene is the fundamental basic and localizable unit in genetics. In spite of all these things, however, we are also forced to admit that a gene remains at present without any distinguishing characteristic unless it is measured in terms of developmental processes which we have been accustomed to call "characters."

For the investigation of such processes laboratory mammals are remarkably, if not uniquely, adapted. With internal moisture and temperature controls, with a relatively continuous type of development, with a life span and size scale

fitted for the detection of minute quantitative variation in rate, extent and form of development, they are as well fitted for the advanced study of the activity of the genes as are any organisms at our disposal.

Those interested in problems of theoretical genetics; those engaged in medicine, sociology, law, theology or education; those interested in human biology, racial modification, or even individual development from any angle, may all combine in awaiting advance in experimental studies of the types mentioned.

The rapid multiplication of mankind has forced the attention of man upon himself and his neighbors. His attention will remain there, his study be focussed there, his major problems will arise there, and there his chief success and failure will be experienced from the present time until a cataclysm reduces his numbers by hundreds of millions, or his control of his own physical and psychological progress, based on sound research, is determined and insured by inspired scientific leadership.

CAN WE LIVE LONGER?

A MEDICAL VIEWPOINT

By Colonel HARRY VANDERBILT WÜRDEMANN

SEATTLE, WASHINGTON

FROM the clinical point of view of the individual the answer to this question must be unqualifiedly in the affirmative, for history shows marked increase in average longevity, biology predicates longer life and science is gradually gaining the victory in the reduction of infant mortality and over-communicable disease.

Let us go to the ancients for a moment and see what was their expectation of life.

The Scriptures state, "And all the days of Methuselah were nine hundred and sixty-nine years; and he died." The average age of the oldest Biblical characters according to this history was five hundred years. We who are living in the progressive Northwest, and not in Tennessee, now know from the evolutionary study of civilization that the ancients reckoned time by the moon, and so the oldest historical character according to this computation would have been seventy-five when he passed on—a fair old age for those times of war, want and pestilence, when probably a virile man begat a hundred or more children, 90 per cent. of whom perished in infancy, three fourths of the remainder before physical possibility of perpetuation of the species.

In the tree-climbing days, before homo sapiens could speak, only those who were most resistant to disease reached maturity, many of them dying early by accident or being killed by savage beasts, or, in times of scarcity, eating their own young and infirm.

[1] Radio addresses, KOMO.

Then came family life with the necessity of protection of its members by the adult male, and the beginning of conflict with his own kind, with killing off the weaker ones at an early age. Then with the beginning of civilization, the clan, the tribe and finally the nation were developed; the strife between the elements causing occasional massed killings and massacres. The most important of all factors presenting rapid increase of the population, however, was the closer bodily contact in houses and gatherings through which infectious diseases were communicated, mainly by parasites of man traveling from one sick person to another person, afflicting them with violent and deadly disease. Only those who had established a certain degree of immunity then survived. Our ancestors were all lousy (pediculosis), daily bitten by bugs (cimex), and they came in contact with all sorts of disease germs. They were daily stung by mosquitoes (anopheles, the malaria carrier, stegoneia, the yellow fever carrier, and others), and fleas were constant companions. They spat around anywhere, spreading tuberculosis and pneumonia. They washed but seldom, their bodily odors being such that they would not be permitted in any modern private house or public assembly. They were indeed a dirty and intemperate lot even up to a few generations ago, and they knew nothing of the prevention of disease before puberty. The young men went off to the wars and were killed or were beaten, tortured or worked to death if they remained on the estate of their

masters. Thus in those days the probable expectation of life was only twenty-five years.

By 1900 it had doubled, reaching approximately fifty years (49.24 years for a new-born baby), and in 1926 had risen to 57.32 years. Even in overcrowded New York City during the last fifty years the expectancy of life has increased nearly 60 per cent. How much better it must be in this favored region of the Northwest, where we have good food, where we lively largely out of doors and where many diseases that depopulate other peoples are but academically known.

Thus by sanitation and the lessening of sanguinary conflicts a certain advance has been made in the extension of human life, and much of this advance through the medical profession, whose work it is to prevent disease as well as to cure it.

But what are we doctors doing to prolong life after disease or injury? It is recognized by physicians and sanitarians that fully one third of the deaths are induced by preventable causes and can be warded off for a time, especially in these enlightened United States of America.

Our whiskey has mostly been taken away from us; diabetes is cured by insulin; syphilis by salvarsan; tuberculosis, typhoid, diphtheria, by inoculation and serums, smallpox by vaccination. Even the common cold, the forerunner of many deadly diseases, is amenable to serum treatment. The people generally know these facts and seek early treatment. Sweeping epidemics of smallpox used to take off 10 per cent. of our ancestors. Now no one should die from it; in fact, no one can take it if properly vaccinated. In my early practice 60 per cent. of children with diphtheria died, now only 6 per cent. There should be no more typhoid or other such diseases as were common up to twenty-five years ago. We know the menace of the house fly, the flea and the louse.

But, how about the reported increase in cancer, in heart disease and circulatory affections which take off 50 per cent. of people over fifty? These are degenerative diseases of advanced life and are apparently more prevalent because they are properly labeled, *i.e.*, diagnosed, and because we live longer. Even within the last few days Mr. Lasker has given to the Medical Department of the University of Chicago one million dollars to study them and so we hope for results such as have come from the Carnegie, Rockefeller, Vanderbilt and other foundations—a wonderful use for these swollen fortunes.

The United States Government through the Agricultural, State, War and Navy Departments prevents the entrance of plague carriers and defectives by more or less strict inspection of immigrants and has instituted researches into the microbic, vegetal, animal and human origins of communicable disease.

There is no physiologic reason why human life can not be prolonged from the present expectation of sixty-five or even that of the Psalmist of four score years and ten. "Yet his days shall be one hundred and twenty years" (Gen. 6:3).

There seems to be a rule of mammalian life that its duration is five times the time of the growth of the bones. This is about twenty years for man. Therefore we should live to be a hundred before the complicated system of cells we call our body ceases to reproduce offspring. In truth we die daily, but these new cells are born every second of our existence.

The cell is immortal and if fed properly, as far as we now know, the pulsation of life may go on forever. But immortality is incompatible with such a highly organized association of cells so senility and death must ultimately ensue.

There are, however, psychologic and economic reasons why some of us should

not live longer. Would not society and the average person be better off were the 2 per cent. of insane, the 5 per cent. of morons, the nearly million of criminals and the five million of asocials, out of the 118 millions of Americans, to die off in early life before they have a chance to perpetuate their defects in their progeny?

Applied eugenics may some day take care of this question.

From the evolutionary point of view of the race as a whole, the prospect is for increase in the average weakness of the adult constitution; for the germ cells seem to be deteriorating through the multiplication of sublethal genetic mutations. In plain language, weak parents are breeding just as many children as ever, which inherit their defects, while those with the best bodies and brains are having smaller families or no children at all. The race may reach the position of equilibrium of equalization which will determine the length of man's days.

It is indeed worth while for the normal individual to live as long as he can be useful to his fellow men. Don't be like Methuselah, whose only result of his 969 years shows in the sentence, "He begat Lamech."

Many of the finest achievements in statesmanship, literature, medicine and the arts have been made by men of sixty or over. Is not Dr. W. W. Keen at ninety-one one of the foremost physicians of the world? Edison is at work at eighty; the statesmen, Arthur James Balfour, eighty-nine; Elihu Root, eighty-two; Von Hindenburg, eighty; Clemenceau, eighty-six. The astronomer Galileo, the philosophers, Herbert Spencer and Lamarck; Browning and Goethe, the poets, Verdi the composer, produced their masterpieces between the ages of seventy and eighty-five. Titian painted at ninety-eight. Sarah Bernhardt and Joseph Jefferson acted at seventy-five. Most of the successful generals in the World War were far past the American War Department retiring age of sixty-four.

It is certain that productive mental activity is greatest after the age of forty, provided that the health of the individual is good and that cares and responsibilities do not take away his ambitions. The preamble to our constitution guarantees the pursuit of happiness to the individual, but he must have his health insured as well as his ambition for productive work conserved to make it worth while to live longer.

The sociologic aspect of long life will be discussed by Professor McKenzie, of the University of Washington.

A SOCIOLOGICAL VIEWPOINT

By Professor R. D. McKENZIE

UNIVERSITY OF WASHINGTON

DR. WÜRDEMANN has shown you that the average length of life has increased considerably during the last few decades as a result of the increasing efficiency of medical science. But what is meant by the average length of life and how great has the increase actually been? The average length of life simply means the life expectancy at birth. In 1920 this was 55.33 years for white males in the United States. In other words, if one hundred thousand babies born on the same day start on the journey of life together the average age at death would be fifty-five years. The Bureau of the Census estimates that during the 120-year period—from 1800 to 1920—there has been in the United States a gain of

twenty-five years in the average length of life. The bureau has published three life tables since the beginning of the present century. The 1901 table places the average length of life at forty-eight years, the 1911 table places it at fifty years and the 1920 table at fifty-five years. It will be observed that there has been a rather rapid increase in the average length of life during the last two decades.

Let it be clearly understood, however, that these gains are for the *average length of life*. They do not signify that the number of persons reaching extreme old age is increasing or that the maximum span of life is becoming greater. In fact, until very recently the life expectancy for all ages over thirty-two years was showing a tendency to decline rather than increase. In other words, until 1920 a person of forty had a poorer chance of reaching say the age of sixty-five than a person of forty had in 1890 or in 1900. The 1920 life table, however, showed a more favorable expectancy for persons of middle life. But it still showed the life expectancy of persons over eighty years of age to be less than for the corresponding age group twenty years previously. Similar conclusions may be drawn from an analysis of the regular census data. According to the United States census for 1920 only 2.6 per cent. of the population had attained the age of seventy years or more. The ratio of this age group in 1910 was 2.3 per cent. of the total population and in 1900 exactly the same. So you see the percentage of persons who reach the allotted span of three score years and ten is remaining about constant. However, when we consider real old age, persons who have attained one hundred years or more, we find a still poorer showing for longevity. In 1880, when the United States had a population of fifty million people, the census listed 4,016 persons as having attained the age of one hundred years or more. But in 1920, when the population had reached one hundred and five million, the number of persons listed as one hundred years of age or over was only 4,267. In other words, although the total population of the country had increased more than 100 per cent. during this forty-year period the number of persons of one hundred years of age or more had increased only 6 per cent.

It is quite clear, therefore, that however successful medical science has been in combatting the diseases of childhood and youth it has not as yet added anything to the maximum span of life. Human existence is a product of two sets of forces: heredity and environment. Longevity, as all physicians agree, is largely a result of heredity. Medical science and social control in general may furnish a favorable environment, but they can not change the hereditary traits of the human organism. Apparently the only way to extend the span of life is by carefully guarding our long-lived stock.

Let us now consider the possibility of further increase in the *average* length of life. It is common knowledge that the recent increase in the average length of life has been due primarily to the saving of babies and children. Fifteen per cent. of all deaths occur among infants under one year of age. Every child saved, therefore, adds about fifty-five years to the possible life of the community, whereas a person saved at the age of say forty-five adds only about ten years. The rapid progress which medical science has made in recent years in combating the germ diseases of childhood and youth is apt to leave the impression that similar progress can be continued indefinitely and that eventually the average length of life may be seventy, eighty or ninety years. Such, however, is not at all likely to be the case. Now that most of the germ dis-

eases are under control, science has to battle with the more profound constitutional ailments, such as organic diseases of the heart, cerebral hemorrhage, cancer, Bright's disease, all of which are on the increase. In this respect the individual rather than the wholesale method must be employed and the results will not be so pronounced. In fact, medical science has already reached the point of diminishing returns so far as the reduction of the death-rate is concerned. During the last few years, according to Metropolitan Life figures, there has been no gain at all in the average length of life.

Then there are other factors to be considered over which medical science has no control. Some philanthropist, such as John D. Rockefeller or Andy Gump, may offer millions for the capture, dead or alive, of the last bug that destroys the human organism, but this does not in itself guarantee that all the enemies of human life will thereby disappear. Man has ways of destroying himself that are quite as effective as those of the invisible parasite. To prove this statement we have only to review the increasing death-rate from violent causes, not to mention that from the so-called degenerative diseases. Our fatal accidents claim one hundred thousand lives a year and the rate is steadily increasing. In 1926 twenty-five thousand persons were killed and seven hundred and fifty-nine thousand severely injured in highway accidents alone. In other words, a city about the size of Bellingham was completely wiped off the map during the year and one twice the size of Seattle converted into a hospital for the maimed and crippled. We are living in a technical age of movement and speed. Every invention that gives us mastery over distance, such as the railway, automobile and airplane, ushers in new causes of violent death. The death-rate from homicides has more than trebled during the last two decades and that from suicides has shown no tendency to decline. The death-rate from drownings is increasing and that from alcoholism has multiplied fourfold since 1920. Unless we are convinced that *homo* is *homo sapiens*—and so far there is no evidence to support such a belief—we can not expect a reduction in the death-rate from violent causes. In a word we can not hope for much greater increase in the average length of life.

But aside altogether from the possibility of increasing the average length of life there is the further question of the desirability of such a result. It is quite clear that any increase in the length of life of competent persons is socially advantageous. And even more so now than in the past, for as society becomes more complex it requires of its citizens more brains and technical skill in the solution of its intricate problems. But by increasing the average length of life we necessarily bring to maturity, and frequently to extreme old age, a host of nature's inferior progeny that would otherwise have fallen by the way.

Considered from a crude economic standpoint society benefits by the death rather than by the life of its misfits. It is impossible to estimate the economic burden that we are imposing upon ourselves by prolonging the lives—or rather the deaths—of socially incompetent persons. According to the latest census figures the United States has in its public institutions seventy-five thousand blind; forty-five thousand deaf and dumb; forty-three thousand feeble-minded—remember this is only the number interned in public institutions, God only knows how many feeble-minded are driving high-powered machines along the highways to-night. In addition there are in our public institutions nine thousand epileptics; two hundred and sixty-eight thousand mentally diseased; seventy-eight thousand paupers, 68 per cent. of whom are over sixty years of age. There are also in this

country over seven hundred thousand persons so severely crippled as to be unable to earn their own livelihood. Then there is the criminal class. The latest census of our penal institutions lists one hundred and twelve thousand steady boarders and four times that number of temporary visitors in the course of a year. This army of incompetents, totalling well over a million and a half, gives a very inadequate picture of the economic burden entailed. It tells nothing about the host of dependent persons who are supported within private homes or by private institutions and agencies.

Of course I do not argue that the best way to deal with social incompetents is to let them die. It would appear to be a much saner policy to prevent their being born. But this is another question, a subject for another debate. The main point to remember is that under present conditions advance in the average length of life is not in itself an unmitigated blessing.

THE OIL GAME

By the Late EDWIN THEODORE DUMBLE[1]

SOME months ago as I was walking along the bank of a creek which flows beside the old ice pond at my home in Virginia, I was struck by the appearance on the water of circles of iridescent colors such as may be seen on any wet street where oil has been dropped from an automobile. "Gee-whiz!" said I to myself. "Did I come up here from Texas to forget there was such a thing as oil only to find oil springs on my own place?" I immediately cut me a stick long enough to reach the colored patches and proceeded to test them. I found indeed that while the colors and circles were quite similar to those of oil they did not have the flow of oil circles, but when stirred they broke into angular portions which did not readily reunite. It was simply a scum of organic or ferruginous matter—and so I was spared the harassing trouble of opening up a new oil field.

Oil as it occurs in nature is in reality a series of organic substances, beginning with light gases and passing downward through oils of various gravities to asphalt, asphaltine and carbon. It usually occurs as a mixture of several grades of these oils and gases.

The questions as to the origin of oil and its manner of formation have been widely discussed without any final agreement having been reached as to either.

We know that volcanoes emit gases of the oil series and that some of these are condensed into oil, but there is not sufficient of this to be of commercial importance. By far the greater part is derived from the decomposition of certain animal and vegetable matters under special conditions. At times this decomposition takes place in the open air and the resulting oil is carried by water and absorbed by sand beds. At others, it seems that the decomposition, in part at least, takes place on the bottoms of very salty lakes or seas, such as the Dead Sea, but the alteration may also take place from remains buried in sediments laid down in salt-water. Apparently salt is a necessary adjunct to the generation of oil, and in some districts the oil is found in direct connection with the salt.

Thus, in the Gulf Coast region of Texas, almost every oil field is located on the apex or flanks of a salt dome.

These domes are the peaks of deeply buried mountain ranges, and the oil and gas have in some manner found their way up the slopes of these ridges and peaks to porous beds along their flanks or on their tops, where the oil is gathered in pools under considerable pressure—hundreds of pounds to the square inch—and held until reached by the drill, when it bursts out as gushers. A part of this pressure is from the included gases, but by far the larger part is hydrostatic and due to the accompanying salt-water.

The salt masses of these domes sometimes reach, nearly or quite, the surface of the ground, as at Jefferson Island in Louisiana. At others the salt lies at depths varying from a hundred feet to two thousand feet or more. Some of these domes afford great mines of rock salt. I was in one a few weeks ago where the salt was being mined from a depth of over five hundred feet, and boring had proved the salt to be in a solid bed three thousand feet below this and at least a mile in diameter.

[1] Formerly state geologist of Texas and later consulting geologist, vice-president and general manager of the oil properties of the Southern Pacific Company.

A part of the decomposition of organic matter which results in the formation of oil is believed to be bacterial. In California, much of the oil is derived from minute animalculae, while elsewhere it seems to be from the remains of plants.

Oil occurs in rocks of all geologic ages and in almost every quarter of the globe, but in many of these it proves to be in too small quantities for satisfactory development. For instance, there are places where the oil occurs impregnating beds of rock hundreds of feet in thickness and extending over thousands of square miles and where the aggregate of the enclosed oil is far greater than the total production of the larger fields—and yet there is no available oil at all. It is simply disseminated through the rock material and can not be separated. It is only where a number of favorable conditions combine that we find the oil pools which yield such stores of wealth and romance. Fortunately for the world there are many such places. In all these cases the oil occurs as actual oil.

Of late there has been considerable talk of the vast deposits of oil shale and the great amounts of oil that can possibly be recovered from them. There is no question as to the existence of immense deposits of these shales in the Rocky Mountain region and on the west coast as well as in Kentucky and other more eastern states. But in none of these does the oil occur as actual oil but rather as potential oil—a substance known as keragin, which is allied to the fats and yields oil when subjected to destructive distillation. Other shales carry resins which similarly yield oil when properly distilled. The possibility of producing oil from these shales commercially is a problem of the future.

From earliest times oil and gas have been known and used in eastern countries. Gas springs and sipes were used by ancient priests to keep perpetual fires on their altars or shrines, and asphalt was used as mortar in the walls of Babylon and elsewhere. History records many uses of the oil in Persia, China and other regions of the east—and it was used medicinally by the American Indians long before the discovery of America.

Its real utilization, however, began with the drilling of the Drake well in Pennsylvania less than seventy years ago, since which time the oil business has grown into one of the greatest industries of the world.

So great was the value of this industry to Pennsylvania that the Geological Survey, under Professor Lesley, made a special study of it and by their work greatly aided in its extension. One of the geologists engaged in this work was my friend, Dr. I. C. White, who decided that as the rocks and rock conditions of the Pennsylvania oil fields could be traced into West Virginia, he could see no reason why the oil pools should not also be found there.

This was the earliest application of strictly geological work to oil field investigation. He found little encouragement among the people who should have been most interested, and finally decided to venture the drilling of a well or wells to prove or disprove his theory. He found the oil and made West Virginia a famous oil and gas producer, and in addition he secured for himself not only a considerable fortune in money but a most enviable reputation as an oil geologist. It was through my personal knowledge of him and his work that I began my investigations in Texas, California and Mexico along the same lines.

The search for oil is really a most entrancing occupation, but possibly it is the enthusiast who knows least about the game who gets the greatest thrill out of it, although there is usually a plenty of excitement for everybody.

It is a great gamble, a game fraught with continual surprises. Many, in fact most, of these surprises prove to be bitter disappointments, resulting as they

do in the loss of time and of much money from drilling and finding only a dry hole. Occasionally oil is struck by the more fortunate and in such large quantities as to bring a rapid rise to wealth unsurpassed by any other calling in the world. It is these occasional yields of great fortunes which are usually heralded abroad, while the losers are quickly forgotten. But even those who fail, time and time again, seem infected with a growing optimism which will not let them acknowledge defeat—and sometimes a change of luck puts them in the ranks of the plutocrats. I might say also that at the present time the oil game is a very expensive one. While our company has had wells costing only three to five thousand dollars that quickly paid for themselves in only a day or two, yet on the other hand we have had wells that cost from a hundred thousand to two hundred thousand dollars that never produced a drop of oil.

I suppose that the average well in the Los Angeles district to-day costs fifty thousand or more. This is not a game of penny ante in which a man of moderate means can afford to indulge.

The discovery of oil is usually due to the occurrence on the surface of the earth or water, of gas blows or oil sipes, which may show as simple colorings and slight flows of oil, or which may expand into pools or even into lakes. In other words, oil very frequently, but not always, discovers itself. Once it is known to exist in a region, however, there are many minor signs which indicate its probable occurrence at different places in the vicinity, such as salt or sulphur water in wells, what is known as paraffine dirt, slight arching or doming of the overlying rock material, etc.; and it is to all these that the searcher for oil gives his attention. Although the surface indications show the presence of oil, close geological study is necessary to determine just how and in what connection the oil occurs, so that it can be traced from these surface deposits to the hidden pools which yield the principal supplies. The geologist also uses the knowledge he gains from such study to find other and similar pools where there are no such surface indications, and sometimes hundreds of miles from the original locality of his work. At present, too, it is the geologist who really directs the drilling and who, through recently improved methods of research, is able to say exactly in what beds the oils of different localities occur and to advise the driller as he passes through the overlying beds just exactly where he is, how these beds are related to the oil and how soon the oil will be struck.

It may be of interest to tell how such an extraordinary thing is possible that we can recognize a bed of clay or sand or rock from a mere handful of fragments brought up by the drill from thousands of feet below the surface when similar beds may not be found on the surface for a distance of many miles. In regions where the harder rocks prevail, such as limestones and sandstones, it is possible to recognize some of them by their composition, color or texture, or by such fragmentary fossils as they may contain; but in our Gulf region, where the materials are uncompacted clays and sands and fossils are very scarce, this was practically impossible until I devised and put in operation an entirely new method of examination about five years ago.

The most of the sands and clays which we encounter in this region were deposited in the salt and brackish waters of ocean, gulf or bay. In all such waters there is usually a wealth of living forms of very minute organisms, which we know as foraminifera. These foraminifera, although too small to be seen clearly by the naked eye, have tests or shells which on the death of the organism fall to the bottom and are buried in the deposits of silt or clay or sand brought out by the rivers from the land. These organisms are as varied as those

of the molluscan kingdom and like them differ for each separate geologic horizon. In fact, each species and variety has its own peculiar shell, many of which are most beautifully marked. All these characteristics are clearly distinguishable under microscopic study.

My idea was that these minute shells might aid us in our studies of oil geology. I therefore at once had collections made from the outcrops of typical materials of all the beds of our region and had these studied for their fossils and foraminifera in connection with material from wells we were then drilling.

The process of handling the material is that it is first soaked and lixiviated until all the clay is washed out and nothing left but the sand and other minute mineral grains and the foraminifera. The forams are then separated by examination under good microscopes. A study of them and comparison with type collections tell exactly what beds they come from. In this way it is possible while drilling an oil well to keep an exact log of the different horizons through which the drill is passing, even though many thousands of feet below the surface of the earth. Hence there has been demonstrated the remarkable fact that a geological study can tell with certainty exactly when oil is to be struck. In fact, this method has been a most successful one in the drilling of wells along the Gulf coast, Texas, Louisiana and Mexico.

To-day also the geologist has the advantage of certain forms of physical apparatus which are of vast assistance in the search for oil in certain districts: the torsion balance, which measures the difference in gravitational effects of the underground beds; the seismograph, which measures the differences in the rate of transmission of shocks from explosions of dynamite through the beds, and the magnetometer, which measures the speed of electrical transmissions through them. By the use of these instruments, unsuspected domes and oil pools are being discovered in low-lying perfectly flat portions of the Gulf coast.

As opposed to the slow but perfected methods of the geologist, we have the rapid work of the wigglestick artist. Those gifted men who, with instruments varying from a simple forked stick of green peach, apple or willow to more complicated forms of apparatus of their own invention, are able, as they believe, to predict the presence of oil and also to give the exact depths at which the drill will reach it. Strange to say, however, their boasted skill seldom yields them the rich returns which should come from successful predictions of this kind.

I have only known of two real successes by wigglestick artists. One of these men succeeded because oil really underlay the whole tract on which he was operating and any well put down would have reached it. He made a fortune out of his first venture, but alas, spent much of it in vain attempts to find oil on other properties where his instrument always predicted it—but the oil perversely refused to be discovered.

This man, a burly doctor, had for his partner a very small man weighing little, if any, over a hundred pounds. After their initial success on the Humble dome they first leased and then bought a league of land (four thousand acres) lying east of the dome because their wigglestick indicated oil at places on the tract. They sunk part of the money already made trying to get oil on the league but without success, and finally they deserted it for pastures new. Later they subdivided the league and leased it to other oil companies. On one of these leases, which was not specially favored by the wigglestick, Cullinan brought in a well which produced a million barrels of oil in ninety days. This gigantic well naturally caused others to drill, with the result that the royalties made the original owners very wealthy. Of course, all the credit for the huge success was given to the wigglestick.

The other success came to a poor Frenchman whose apparatus seems to have had some real merit in that he actually did foretell in three or four wells not only the depths but the character of the oil which would be found. One of the owners kept me advised during the drilling and was very positive that this was true. Unfortunately for the Frenchman, he was working without a written agreement. The owners took advantage of this and refused absolutely to give him any interest in his discoveries or to pay him for his work, which proved to be worth millions to them. He died of a broken heart. A twenty-seven story office building erected in the south by the widow of one of those he made rich is in reality a monument to the Frenchman!

Still another method of finding oil is the hunch. One of our luckiest operators told me this tale of how he located one of the famous fields of north Texas. He said he felt a hunch that there must be oil west of Fort Worth and just south of Red River, so he and his brother with one or two others started to look for it. They traveled westward for several days examining the country, and finally not having seen anything that suited their fancy, they started back. That evening as it was getting dark a black cat crossed the road just in front of them. "There," cried my friend, "there is my oil field."

They marked the place, went on into the nearest town for the night, and next day went back and made their leases—and soon brought in a field that after many years is still producing.

But how about the thousands of other hunches that did not pan out?

And then some of our good friends were always so anxious to help us in the finding of oil! One man brought us word of a well that had been drilled on the west coast of Mexico, saying he had been there and had seen the oil. I started a man from San Francisco by steamer for the nearest Mexican port. From there he had to take a sailboat down the coast and go inland by mule train. He found the well and the oil—but somehow the oil did not look exactly right to him. So he spent a few days searching the hills and finally ran upon a lot of tin cans that had held lubricating oil, and so solved the origin of the oil in that well.

Another report of an excellent oil sipe was brought us by some one who had found it on the banks of a creek north of Spindle Top. I sent out to examine it at once. My assistant found it easily and it was a real sipe of good oil, but he could not see exactly why there could be a sipe at that particular place, so he concluded to do a little digging. He did not get on very far before he found a small pipe, and following the pipe he found a barrel of real Spindle Top oil buried in the creek bank high enough to let the oil flow slowly to the wonderful sipe—and that was that. Many such plants have been carefully and deliberately arranged with a view to giving enhanced oil values to ordinary farm lands.

As I have stated, several of the great oil fields of California, Texas, Oklahoma and Mexico actually discovered themselves. In California the asphalt deposits of Rancho La Brea, near Los Angeles, itself a marvelous graveyard of prehistoric animals and birds, the extensive asphaltic sand beds of Ventura and other coastal countries, the asphalt beds and oil and gas sipes extending up the San Joaquin valley from Sunset and McKittrick to Coalinga, all proved the existence of oil before we ever began to drill for it. We knew for certain that the oil was there somewhere, and our work was to find just where it was and how it occurred. It was my great pleasure to have done this most successfully for the San Joaquin Valley region where the great bulk of the Southern Pacific lands were located and to have been one of the principal instruments in this development. My work

and that of my assistants outlined and developed much of the oil-bearing territory which is now pouring out its streams of black gold in the Los Angeles district and around Ventura. In fact, it was the possibilities of this area, as I presented them to Mr. Harriman in the year 1903, that caused the conversion of all Southern Pacific locomotives from coal burners to oil burners.

In Texas, the oil and gas sipes at Sour Lake, Saratoga, Batson and elsewhere were well known and attempts at utilization made many years before the oil boom. As early as the year 1892, drilling was in operation at Spindle Top in order to reach the oil believed to be there. As state geologist I cooperated with them and had an observer located at the well, which, however, could not be drilled deep enough because the method used, that of the old percussion drill, was not suitable.

One Monday morning in January, 1901, I reached El Paso on a trip from San Francisco to Houston. The morning papers were ablaze with the news of a great oil well brought in the day before at Spindle Top. Trains were slow in those days and it was Tuesday night before I reached Houston. Early Wednesday morning I was at Spindle Top to see the wonder of the world—as it was then thought to be. It really was a remarkably great well and marked the beginning of an epoch in the history of the Gulf coast and of Oklahoma. Captain Lucas, by the use of the rotary system of well-drilling, had succeeded where the previous operators had failed.

A scramble for wealth was started that was unequaled even by the great rushes of the Pacific slope.

In Oklahoma, I had called attention to the asphalt deposits near Ardmore as early as 1894 and had made an effort to secure their development. Others had pointed to similar deposits elsewhere in the territory (as it was then). As a natural result, the later successful exploitation of the Texas fields brought their development also.

In 1888, my assistant and friend, Mr. Josiah Owen, one of the most competent geologists I have ever known, made a trip into the Tampico region to examine the asphalt lakes of Mexico. Ten years later I made a strong effort to induce Mr. Huntington to look into the matter and develop the oil, but he thought the deposits were too far from his railroad lines to interest him. Not long after, Mr. Doheny went to Ebano and found some heavy oil. In 1907 or 1908, Mr. Harriman wired me to look into it and we did so. The result of our work and that of other companies who followed us, influenced in part at least by our action, developed phenomenal fields in that region and produced one well which as nearly as could be measured yielded oil at the rate of 265,000 barrels daily, so far as I am informed the very largest yield in the world's history.

Now it must be remembered that all this great pioneering work was done, and all these thousands and thousands of miles were traveled, before there were any automobiles, and when, outside of the railroads, which had a way of going anywhere but where we wanted to go, we had to depend on horses and wagons; when fifty miles a day was an outside limit and thirty-five a fine average. And yet even this had its great advantages, and we certainly did closer work than our automobile partners do nowadays. One of the best observers in South Texas said to me a few days after a new dome had been discovered—at least it was new to them though not to me: "You early workers certainly had the advantage over us in travelling by wagon. I have gone over that dome a hundred times at thirty-five miles an hour and never suspected it—while had I gone in a wagon I see now I could not have failed to know it was a dome." So our slow locomotion was not so bad after all.

When I went to California in 1899, the city oil field in Los Angeles was well developed, there were a number of wells at McKittrick and others between Los Angeles and Santa Barbara, but the total production was rather limited. Outside a publication or two by the state mineralogist, there was very little information regarding the oil geology, and neither then nor for many years afterward did any company except the Southern Pacific pay any real attention to this side of the business.

My idea was that geology should be made the basis of all real oil development, and in organizing the work in California I always planned with that end in view. The geological method proved to be a great success from the very start and while the history of the opening up and development of its oil lands by the Southern Pacific had nothing of the spectacular about it we made a steady advance and the results to the Southern Pacific ran into hundreds of millions of dollars. This great financial success, which was clearly the result of our geological work, caused geological methods to be used by more and more oil companies until to-day the geologist is an absolute necessity with all of them. And this result is equally true in all the more recent fields.

Along the Gulf coast on the contrary, we were anything but quiet. At times, it was more like a stampede. Wells were drilled at any old place, with or without reason, and sometimes, even when there was no apparent reason, they found oil—wildcats of the wildest breed—and whenever there was a sign of oil, land prices soared and people fell all over themselves trying to purchase or lease. Companies were formed and stock sold broadcast over the United States on any basis or no basis. On Spindle Top, lots twenty by twenty were sold at $2,000 each and upward, a total of over $200,000 per acre. Needless to say many of these never paid for themselves, although others were cheap at the price. We had one or two of these. The difference was not in the actual oil value of the ground, but in handling it so as to get your share of the value as soon as possible. It was a great and mad scramble. Nevertheless, to have gone through it and to have experienced the exhilaration and tingle of excitement, to have breathed the air surcharged with the gambling urge, to have seen the really great deeds that were done, to have known the men who did them and at the same time to have been an integral part of it all, was to have really lived.

The Spindle Top field had a total area of only four hundred acres, yet on this small area there were thousands of wells drilled, and it has produced more than seventy million barrels of oil. While it was commonly spoken of as "the hill," the rise from the surrounding level prairies was so slight that it was scarcely to be noticed by an ordinary observer, and during its early development it was frequently surrounded by seas of mud, which at times were all but impassable. In fact, this was the case with many of the coastal oil fields—the finding of a new field seemed to be the signal for regular downpours of rain with the result that the wagons and teams stirred the stiff black prairie soil into regular quagmires.

The early production at Spindle Top was so great and the sale so restricted that the price fell to as low as five and six cents a barrel. With oil at this price, it was not considered such a venial sin to appropriate some of what was really your neighbor's. The oil flowed from the wells into pits and was pumped from them through pipe lines into large steel tanks located at some distance from the field. One morning going over on the train one of the large operators told me in great glee, "Do you know I have cut in on Higgins' pipe line and every time he pumps to his tanks he pumps part of his oil to mine." And this was by no means an exceptional occurrence.

Later when oil became more valuable the scene was changed and I remember we sat up two nights with shotguns waiting for the man who had cut in on one of our lines to come and turn the valve. He did not come—so we broke the connection and let it go at that.

As time went on and wells multiplied at Spindle Top the derricks in some parts of the field were so thick that they actually touched. And then came sweeping fires which wiped them out by the score!

Then also came the deadly gas which killed numbers of workmen and blinded many of the others totally or temporarily. I remember one night the gas from one of the wells in the Batson field killed all the men who were sleeping in a bunk house nearly half a mile away—and two or three days later when I had occasion to go that way, my companion and I, although we thought we were giving it wide enough berth, both had our eyes affected by it. Fortunately this gas only occurred in two or three fields and gradually died out in them.

As the supply of oil decreased at Spindle Top it ceased to gush or flow naturally so it had to be pumped and as the months sped by the production grew gradually less until finally salt-water began to make its appearance and one by one the wells were abandoned and the field was turned over to small operators or strippers. In this brief story of Spindle Top, I have given you the story of all oil fields. They come in with a rush, rise to their culmination and then decline and are finally flooded with salt-water.

When the salt-water first came into the Spindle Top wells in quantity some of the folks insisted that the Standard Oil Company were pumping it in from the gulf in order to destroy the field. It gradually destroyed the field all right, but the sin was one from which the Standard Oil Company could claim immunity.

The history of Spindle Top was repeated in field after field on the coastal region of Texas and as the supply of oil decreased there, attention was directed to Oklahoma and north Texas which had similar experiences with great yields of oil as the years passed one by one.

Thus the game has gone on in this region for twenty-five years, new fields taking the place of old, new players chipping in in place of those who have dropped out, colossal fortunes being made and lost. From present appearances this game is likely to continue a full lifetime yet. And there are always other fields! Do you wonder it has its devotees?

The principal holding of the Southern Pacific Company in south Texas was the Saratoga field in the heart of the Big Thicket, twelve miles north of Sour Lake, from which point we had to drive by team. When we first took over the property, there were a number of nesters or squatters on it who made their living raising razorback hogs and hunting the deer and bear that were so plentiful in the thicket. They notified us at once that if we attempted to develop the property our rigs would be burned and we would be worried in every possible way. For years I had had as my assistant Professor Cummins, a Methodist preacher and a good geologist. I called him in and told him I was making him manager of the Saratoga field and that his job was primarily to get rid of all the nesters in a friendly way and see that we had no trouble with them. Within a few months every one had either moved away or was working for us and some of their children are still in our employ.

When we bought the property there were two or three lots on the inside we could not get possession of. A little later a noted gunman who lived at Korentz, some twelve miles east, let it be known that he was going to put up a saloon on one of these lots if he had to do it at the end of his gun. Finally he

came to Saratoga, and when Professor Cummins heard of his arrival he hunted him up. After introductions Professor Cummins said to him: "I understand that you have made your boast that you are going to put a saloon here if you have to do it at the end of a gun. Now I want to warn you that if you attempt anything of the kind, you want to be mighty sure of which end of the gun *you* are at." The professor was an old Indian fighter among his many side lines, and I suppose his manner carried conviction as to his meaning. Anyway the man soon calmed down and told him that if he would consent to the saloon he would promise that it should never be rough house in any way. So it was put there and the man was the professor's firm backer from that time on, so that once during a strike when threats were made against Cummins the saloon owner buckled on his guns and sent the strikers word that it was his fight—and it stopped.

One January day in the early history of the field the president of the company and I drove over to inspect the operations. It began to rain in the afternoon, so we decided to spend the night at what was called a hotel. It transpired that there was only one vacant room and one bed, but it was that or nothing. When we finally got to bed we found it already abundantly tenanted and, as if that were not enough, the storm broke again with a play of lightning and thunder and a deluge of rain that contributed to the miseries of the night.

Next morning we found that we could not get away until the creeks ran down. Our scouts said they would be all right by eleven o'clock anyway, so we started out at that time with a cold norther blowing. When we came to the first creek, it looked pretty wide, but the driver said he could make it all right, although the water might come up into the carriage. So we took our grips out from under the seat and stood on the doors holding the grips high enough to escape the water. We got through very nicely. The horses had to swim a short way and we were wet to the knees, but congratulated ourselves on getting off so well. We dried the carriage as well as we could, put our baggage back under the seat and started on our way. The next creek was not nearly so wide and looked all right, so we started bravely in. The horses suddenly gave a lurch and a spring and before we could catch our breath we found ourselves still sitting on the seat but with the water of the creek up to our arm pits—and cold! We still had six miles to drive to Sour Lake and nothing dry to put on when we got there. However, the hotel man gave us a big room and a big fire before which we basked *au naturel* while our garments and belongings dried.

Such incidents as these were regarded as simply part of the game and added zest to its pursuit.

There is, however, another side to the oil game which is not so pleasant to tell about. As long as men are men the successful man will be the mark of those less fortunate and greed is ever to the fore.

My own experience is that of a scientist and a manager of fairly large producing companies which had only a limited sphere of operations. But this gave me full opportunity to see the bad side of the game. I have seen the bitter contests of smaller companies, fighting for their lives, battered and held down by those of greater power who had or could control facilities without which other producers could not market their oil profitably. I have seen the employees of these larger companies use every means to prevent their competitors from completing wells. I have had them actually pay drillers who were working on my wells to hold back my work until they could complete their wells and so get the flush production, and also have had them, in the absence of our men, fill a well with junk so that we had to abandon it after

spending over twenty thousand dollars on it. I have seen great contests for control between the greater companies in a field where most ruthless methods were at times employed—but of late years it has proved more profitable to use the merger and so we have had less of this. Still, strong-arm methods are not entirely wanting even now!

What is true in our individual fields is just as true of the world at large. The control of the oil fields of Rumania, of Mosul in Turkey and Baku in Russia were undoubtedly large factors in the great world war. And these are figuring strongly to-day in the realignment of European politics. Thus the mandate for Iraq which was given to Great Britain covers the control of the Mosul oil field, and this was done over the protest of the Turks.

Germany is striving for control of Baku and it is stated that she has contracts with the Soviet government which will help her acquire it, and Rumania is largely given over to outside control.

To the uninformed there might not appear anything very wrong in this, but it must be remembered that for years before the war these various fields were in possession of and operated by private owners and that this new governmental control changes all this and practically cancels the original private rights in favor of those approved by later governments.

Our own present trouble with Mexico is largely because of the oil question and grows out of her effort to prevent the depletion of her oil fields by foreigners.

It is true that many of us went into Mexico and acquired our lands and produced and shipped our oil in strict accordance with the Mexican law. But there were many others who did not and some who even used their money to debauch the people and the courts in order to attain their ends. To illustrate: In a trial for ownership of a certain tract of oil land, the Supreme Court awarded it to us and ordered the local judge to put us in possession. Our opponent bought the local judge and put private guards on the property to prevent our getting it. Later we got the matter into the court again and before a judge whose probity was acknowledged everywhere. On the trial we had the law and evidence fully in our favor and expected an immediate decision that way. The decision, however, was not made until the following day and, strange to say, was against us. Our lawyer called on the judge and asked his reasons. The judge pulled open his desk and showed a big roll of money. "My God! man," he said, "what else could I do? They gave me 7,000 pesos." When this fact reached Mexico City the judge was deposed and the head of the company giving the bribe was called before the president, who told him that too many reports had reached him of such practice by his company and that it had to stop, and that he must leave Mexico at once and not return under penalty of immediate arrest.

Many other ways were used to get around the Mexican laws and the actions of some of the companies were notorious. The Mexican government seized this and similar wrongful acts perpetrated by or attributed to foreign oil companies as the basis for the claim that the country was being robbed by the foreigners. They then proceeded to enact laws ostensibly to correct these evils, but which in reality seem to be intended as confiscatory and to force the foreigner to turn his properties over to Mexicans or the Mexican government.

All the world over, therefore, oil is a game, a very great and at times a highly remunerative game, but, I am sorry to say, it is not always played fairly either by the individuals, the corporations or the governments.

THE CONTROL OF CRIME

By Dr. EDGAR A. DOLL
THE TRAINING SCHOOL AT VINELAND, NEW JERSEY

FEW questions of national welfare have caused such widespread discussion as that of the control of crime. But probably no question of equal importance has developed more confusion of thought and action. Positive statements from all quarters of public interest leave the ordinary citizen in utter uncertainty regarding the most effective measures to be taken toward wiping out what has widely been termed "our national disgrace." Most of the alarmists recognize only specific causes of crime and ingenuously advocate panacea methods of prevention. But the real difficulty, and yet the one which seems least often emphasized, is that crime is caused by an intricate complex of related influences and that the control of crime requires intelligent cooperative effort.

Thus some find *the* cause of crime in the automobile, the "movies," the dime novel, the dance hall, the broken home, the un-Americanized foreign-born. Others believe the cause lies farther back, in the "fence," commercialized vice, the master-mind, the "higher-up," official corruption, and such. Still others claim that crime is caused by human weaknesses in the criminals themselves, such as feeble-mindedness, insanity, warped personality, uncontrolled appetites, and the like. Likewise inadequate law enforcement, obsolete criminal laws, weak administration of criminal justice, loopholes in judicial procedures, abuses of judicial discretion, unrestricted release of habitual criminals after perfunctory sentences impress many observers as responsible for widespread criminality.

There can be no doubt that all these and similar influences are potent causes of crime. But how do they operate in specific instances? The public is seriously uninformed if it still believes in Lombroso's "criminal man" as a prototype for all criminals. In the jails and prisons of to-day we see plenty of human frailty but not many "instinctive criminals." Likewise the public, lay or professional, is curiously naïve when it accepts such simple social explanations of crime as are specific to our day and age. Was crime less before we had movies? Did the automobile produce crime as a new social phenomenon or did it merely give crime a new *modus operandi*? Was there no robbery before the "fence" was built up or is the "fence" merely a new organization for robber barons and poachers? Crime has always attended the looser forms of public recreation. Official corruption is as old as officialdom. Poverty, vice, personal excesses, prodigal sons, wayward daughters are all as old as history. Public indifference is as old as society.

It is a social axiom that a specific crime requires both a person and a situation. It is a psychological axiom that human nature does not change, although new environments may bring new forms of self-expression. Appetite, passion, ambition, dishonesty, cupidity, indolence, emotional instability, weakness of intellect and of will are some of the human traits which, *acting always in combination* with such social situations as arise from poverty, oppression, illicit association, unwholesome recreation, inadequate protection, display, license, corruption and indifference, produce specific criminal acts. The potentially

criminal person and the potentially criminal situation each requires the other before crime can occur. The nature of the crime depends somewhat on both. In some degree this combination of human and social circumstances is fortuitous. In general, the criminally inclined person capitalizes his criminal opportunities and the upright citizen avoids temptation. But just as there are many degrees of criminals, from the short-weight grocer to the embezzler, so there are many degrees of criminal opportunity from the untested scales to the careless handling of the bank's millions.

When we accept these elementary principles we shall be on a new road to intelligent thought in this matter of crime prevention. Our present classifications of crime are based on the social acts themselves—murder, arson, rape, robbery, assault, fraud, and so on through the list. We are only recently developing any adequate classification of criminals, as casual or habitual, normal or subnormal, stable or unstable, sane or insane. The human disposition of the individual is the predisposing factor, and the social situation is the precipitating factor in determining the specific character of the criminal act. *Both are essential* in studying the causes of crime and the consequent methods of prevention.

It ought not to be necessary to call attention to the large body of authentic literature dealing with crime from a technical and professional point of view involving all the relationships such as have been mentioned. Even a casual review of such publications as are contained in the Modern Criminal Science Series[1] is sufficient to give such a fundamental orientation. The most modern scientific theory of crime is that of Ferri and is more than fifty years old. Ferri states that:

> Crime is the result of manifold causes, which, although found always linked into an intricate network, can be detected, however, by means of careful study.

And further he says:

> Crime is a phenomenon of complex origin and the result of biological, physical, and social conditions. *Certainly, the dominant influence of this or that factor determines the biosociologic variety of the criminal, but there is no doubt that every crime and every criminal is always the product of the simultaneous action of biological, physical and social conditions.*[2]

More than fifty years ago the complex causes of crimes and the methods of their prevention were embodied in a declaration of principles promulgated by the American Prison Association. In the meantime a general sentiment has developed throughout the country that crime is on the increase, and this has created an insistent demand for more definite and more cooperative action. Various crime commissions and a number of local conferences have suggested programs of action.

In formulating such a program, designed to promote the cooperation of all agencies interested in the reduction of crime, it is obvious that since crime is the result of the interaction of men to their environment, and since the causes for those acts which we call criminal are found both in the individual and in his environment, therefore no program of crime prevention can be considered adequate which does not include a comprehensive consideration of human characteristics and social forces as they react upon each other.

Such a preliminary analysis of the situation reveals at least seven major groups of conditions within which most of the influences related to crime can be encompassed. The enumeration of these influences, with some illustrative detail,

[1] Published under the auspices of the American Institute of Criminal Law and Criminology, Little, Brown & Co., Boston.

[2] Italics ours.

constitutes in itself a suggestive program for cooperative action. The need for further detail on each of these influences will be obvious.

(1) *Statistics.* The current interest in the reduction of crime is largely due to the popular belief that crime is on the increase. This belief is no doubt caused by the large number of sensational crimes and the widespread dramatic publicity which attends them. Certainly the increases in population and in complexity of economic and social organization might be expected to produce an increase in crime in spite of reasonably successful efforts toward crime prevention. Certainly also the improved facilities for news gathering and publication give the public a much wider knowledge of the seriousness of crime as a national menace. But what are the facts? Is crime actually on the increase? Are there significant changes in the relative frequencies of the different types of crime? Are there significant differences from a statistical point of view in the nature of crime and criminals? Are the available statistics reliable? Are they comparable? In other words, what are the basic facts regarding the present crime situation as to such items as: crimes actually committed, criminals apprehended, convictions secured, punishments meted out and criminals rehabilitated. Do criminals actually graduate from the streets to the gang, from the gang to the jail, from the jail to the reformatory, from the reformatory to the prison, and from the prison to a life of habitual criminality? What do we know statistically about recidivism? Obviously, any intelligent analysis of crime prevention must be founded upon accurate knowledge of the actual facts in order that we may "apply the oil to where the squeak is." At present most public statements can not be substantiated by reliable figures, for the statistical data are hopelessly incomplete and incomparable

(2) *Predisposing conditions.* Crime obviously arises initially through a number of predisposing conditions, material, environmental and individual. In certain more or less fortuitous combination these produce precipitating influences and reduce potential criminals to overt offenders. Among these predisposing influences may be mentioned such details as unsegregated mental defectives, unprotected minors, bad housing conditions, inadequate public health supervision, uncontrolled drug and liquor traffic, inadequate supervision of public recreations (movies, dance halls, road houses, night clubs), broken homes, low social standards, poverty and economic handicap, extravagant taste, unreasonable ambition, and such others as are epitomized in the time-worn expression "wine, women and song." What do we know and what can we do about all these conditions as causes of crime?

(3) *Opportunity for crime.* Somewhat analogous to these predisposing conditions are those influences which create precipitating conditions. Garofalo calls this the opportunity for crime. There are "natural" crimes arising from instinctive or emotional causes and "artificial" crimes arising from social institutions or political conditions. There are crimes against chastity, against honor, against the person, against property and against modern laws. We may mention such details as inadequate protection of person or property, provoking or careless display of valuable or personal effects, abuses of insurance and bonding, careless trust of strangers, advantages taken of political power or of business conditions. There is also much ignorance and disregard of laws making possible even unintentional misdemeanors or felonies.

(4) *Criminal law.* Many authorities

believe that the continuance of obsolete laws or of indefinite laws or of unpopular laws creates situations which engender disrespect for laws in general with consequent social disorder. There is also much antiquated legislation which obstructs police and court procedures, such as rules of evidence, technicalities, systems of appeal, unequal or unreasonable penalties which aggravate rather than ameliorate the control of crime. Other laws may be ineffectual, nonexistent or subject to abuse, such as those providing for adequate systems of probation, pardon and parole, indeterminate sentence, restitution following criminal offenses, control of the criminal "fence," control of habitual criminals, control of deadly weapons and similar items. We must reckon with existing abuses in the selection and control of juries and in the whole machinery of our judicial system, such as rules governing expert testimony, loopholes in prosecution, judicial discretion in sentence, probation, place of commitment, fines *vs.* imprisonment, and so on through a long chapter. In this whole group of influences we are concerned especially with the administration of criminal justice and the need for honest and courageous application of such legal procedures as do exist and might be more effectively employed.

(5) *Law enforcement.* Under this heading are those influences relating to the speedy apprehension of criminals, including adequate policing, vigorous pursuit and detection of criminals, methods of criminal identification, cooperation of detection and policing agencies as between cities, counties and states, the centralization of policing authority and methods for the exchange of criminal information. If there is one thing we are sure of in experience it is the fact that speed and certainty of punishment and not severity are the greatest deterrents to crime.

(6) *Punishment and correction.* This group of influences relates to problems in the administration of penal institutions and methods of preparing prisoners for release, such as disciplinary conditions in jails and in penal and reformatory institutions, sanitary conditions, systems for the intelligent classification of prisoners according to mental, physical and social tendencies, facilities for correctional treatment (medical, moral, industrial and educational) following such classification, industrial employment and training of prisoners, provision for self-government, methods of release and so on. Great progress has recently been made in controlling this group of factors.

(7) *Rehabilitation of offenders.* This group includes problems of probation and parole, including methods of determining suitability for release, means for restoring released offenders to sound industrial and social standing, adequate correlation between the penal institution and the community, adequate systems of probation and parole supervision, and so on. The more widespread use of scientific methods in studying the individual convict before release is one of the most significant advances in modern penology.

It is obvious that at least these manifold factors must be studied in further detail with reference to their interrelationships before we can successfully control crime in this country. Vigorous effort can accomplish something in any or all of the above divisions and we must not relinquish our endeavors to advance each portion of the above program separately as well as coordinately. But it takes little imagination to see the need for immediate national coordination of all the many agencies dealing with the problem all along the line, from the initial social situation which predisposes individuals toward crime through all the many steps prior to the successful

rehabilitation of convicted offenders. To promote this coordination it will be necessary to harmonize the numerous influences involved, urging each interested group to carry its own responsibility into action rather than to point to the breakdown of other agencies concerned and also to cooperate fully with such agencies. Our principal need is an intelligent program of prevention. But for crimes that can not be prevented a program of correctional treatment is equally important.

The practicability of such cooperation is effectively witnessed by the recent conference called at Washington by the National Crime Commission, which successfully brought together a large number of interests from the above-mentioned fields and undoubtedly promoted a much more intelligent understanding of the many problems involved as well as a larger and more vigorous national interest in the whole question.

How may increased coordination of effort be brought about? How can the numerous agencies concerned with the control of crime support each other and at the same time increase the success of their own efforts in their special fields of endeavor? Obviously such cooperation requires some central correlation. We need publicity, official support and leadership, and these must be imaginative, vigorous and sincere of purpose. Such cooperation must be both local and national, for the character of crime varies with geographical and political conditions.

At present this centralization of effort can best be promoted through the various crime commissions, municipal, state and national. These commissions are or should be conversant with local and general situations. Composed as they are of men of affairs and influence, they are in an excellent position to serve as rallying points for the promotion of such a program as might be subscribed to by all concerned. But while these crime commissions might be expected to advocate the most effective methods of crime prevention, they at present seldom do so because as now composed they do not represent all the interests vitally concerned with the problem. To offset this serious defect these commissions might be enlarged by the appointment of outstanding representatives from all the major interests concerned with crime prevention. Or the crime commissions as at present constituted should appoint advisory committees of representatives from each of the seven fields of interest cited above. These committees acting as advisory groups to the crime commissions could then be instructed by their respective commissions to formulate programs which the commissions could adopt with a reasonable prospect of practical success. The commissions could then utilize the various legislative, administration, business, social and technical resources of the country in a concerted attack on the problem. Then these crime commissions instead of advocating programs obviously narrow, unimaginative or uninformed could promote a program of unified intelligent action supported by the best public and professional thought on the subject and could promote a widespread campaign of publicity designed to stir up that interest on the part of the general public without which no program can be carried into action.

These various crime commissions with an adequate program based on technical advice should then be developed as clearing-houses and as research centers for the collection and dissemination of information and factual material. These clearing-houses by promoting a demand for information relating to criminal statistics, the administration of justice, the conduct of correctional institutions,

methods of community protection, and the like, would have a wholesome effect at once in bringing to a higher level of efficiency the already organized public and private efforts for crime prevention and control. These crime commissions, through fact-finding agencies, and even perhaps with their own research personnel, could analyze and correlate the multiple influences tending toward the production of crime and could evaluate the success of various efforts toward the reduction of criminals.

Finally, while we insist that crime results from the interaction of men to their environment, there is already a preponderance of evidence which shows that the criminal person is much more important than the criminal situation. We have been a long time learning that the individual tends to create his own environment rather more than he is created by it. Biological forces are relatively permanent, although the form of their social expression is extremely variable. This in itself tends to show man's control of his environment, for he selects and modifies the conditions under which he carries on his existence. Certainly the scientific study of the criminal himself is to-day the most tangible means of dealing with the prevention of crime. This is evident in the fact that most social legislation intended to reduce crime is directed more toward the human factor than toward the social factor. Since Lombroso, and more particularly since the recent advances in the social sciences, we have a new weapon in dealing with criminals which if effectively used would give us instead of him the whip-hand in reducing this menace to our social welfare.

LIKE FATHER LIKE SON-IN-LAW[1]

By Dr. DONALD F. JONES

CONNECTICUT AGRICULTURAL EXPERIMENT STATION

In the movies the policeman's daughter marries the banker's son and—we are led to infer—live happily ever after. This happens so seldom in real life that the plot is always entertaining, and as citizens of a thoroughgoing democracy, where every individual is as good as every other, if he can prove it, we applaud enthusiastically. This enthusiasm may be entirely absent in the rare event occurring in the banker's own family, but even in their disapproval most people feel somewhat apologetic, as if this attitude were contrary to a worthy ideal which should be everywhere upheld.

This way of thinking is founded in part upon the customary rule that people having opposite characters should marry: tall with short, fat with lean, blond with brunette, stolid with vivacious. While we are told that the bringing together of dissimilarity in physical characters and in temperament are conducive to conjugal happiness, let us see what people actually do in this respect.

In the biological journal of statistics, *Biometrika,* there is an article by Professors Pearson and Lee which gives the results of their studies in England on the similarity of married couples with regard to such easily measurable characters as height, span of arms, length of forearm, color of eyes and longevity. Surprising as it may be, they found that husband and wife are more alike, even in these less important qualities, than first cousins. The size measurements were made upon the parents of college students from widely separated districts, and the results are considered not to be affected unduly by marriages occurring within different local races which might show an apparent correlation when none actually existed.

This opportunity for error was also carefully ruled out in their investigation of longevity. In this study the ages were taken from tombstones in two rural communities where the people belonged to the same racial stocks and seldom moved from the community. Data were also taken from the very complete records of the Society of Friends. There is a tendency, which was fully recognized, for the husband and wife to be buried in different localities when their deaths occurred at widely separated intervals, and for that reason the larger differences would not be included in the tabulation. This was borne out by the figures obtained from a London cemetery which showed a much closer agreement in age at death than from the rural communities. Undoubtedly the failure to include the more negative pairs was responsible for this. The authors carefully considered all variable factors which might give a relation not based on similarity in length of life and concluded that there is an assortative mating of people of nearly equal vitality as measured by the life span.

A tendency toward a longer or shorter length of life is definitely inherited, as shown by Professor Pearson and by Dr. Pearl. Long life is an indication of general constitutional strength. It has also been shown that the similarity between husband and wife is greater among the parents of adult children than it is for childless couples, so that the mating of like with like is a factor in fertility and consequently tends to perpetuate itself.

The influences which tend to prevent inter-racial unions involve much more

[1] The data upon which this article is based are given in "Selective Fertilization" in the University of Chicago Science Series published by the University of Chicago Press, 1928.

than physical differences. The whole social inheritance, customs and folk-ways separate not only races but different political and religious groups as well. Wealth and social position are notable factors in determining conjugal ties; and, since these have some basis in mental ability, inherited intellectual capacity is an important agency in determining the partners in matrimony. Terman's studies on gifted children bear this out. The parents of children which stand high in the intelligence tests are themselves distinctly above the average.

An explanation for this tendency for like to mate with like has been put forward by the behaviorists. The young man in seeking his life partner instinctively chooses a girl who is like his mother, while the young lady considers favorably only those men who are, in some respects at least, similar to her father. Since, as we shall see later, homogamy is a common practice throughout the animal kingdom and a similar situation exists in plants, is it not probable that there is involved here something of a far more biological importance and racial significance than this rather superficial explanation would indicate?

If man is an animal, as biologists insist, the mating instincts of lower forms of life should have interest in this connection. Plants are also bisexual organisms. Is reproduction among them purely a matter of propinquity?

The lowest organisms, if we may judge from the evidence from the single-celled Paramecium, do not mate at random. Each individual not only refuses to mate with members of other species, but successful pairing takes place only when the partners are alike. This is shown by the extensive observations of Professors Pearl and Jennings, of Johns Hopkins, who find a significant correlation in size, the only character that could be measured, in the conjugating pairs of this species.

In another protozoan form, it has been observed that individual members of the same culture differed as much as 14.5 millimeters in length, but no two members of a conjugating pair differed more than 5.5 millimeters. Out of 279 pairs, thirty-five were equal and only seven pairs differed more than 3.5 millimeters.

Going somewhat higher in the animal scale, there is evidence from the mollusks of an assortative mating. The hermaphroditic nudibranch has been carefully studied by Professor Crozier, of Harvard, who observed that in most cases large individuals mated successfully with large, and small individuals with small at various seasons of the year. Two different species of this animal frequent the waters about Bermuda, but they have never been seen to hybridize under natural conditions; and even when confined in small dishes the two species could not be induced to mate.

Among crustaceans and insects the same condition holds. In two similar species of fruit fly, Dr. Sturtevant, of the Carnegie Institution, has noted that the females of either species are far more likely to unite with males of their own species than with those of the other, although the males court females of either species apparently without discrimination.

The results carefully compiled from a few widely separated groups among the lower animals show a definite tendency for similar individuals to take part in reproduction. The situation among the higher animals is indicated by a number of observations taken from Darwin's "Animals and Plants under Domestication." The Alco dog of Mexico dislikes canines of other breeds, and the hairless dog from Paraguay mixes less readily with the European races than the latter do with each other. In Paraguay the native horses which run loose on the plains associate with each other according to color, and horses imported from other districts tend to remain aloof. In Circassia several subraces of the horse

live a free life. They refuse to mingle and cross and will even attack each other.

In England the heavy Lincolnshire and light Norfolk sheep, though bred together, when turned out on pasture separate to a sheep in a short time. On one of the Faroe islands not more than half a mile in diameter, the half-wild native black sheep are said not to have mixed readily with the imported white sheep.

Dark- and light-colored deer which have long been kept together in the forest preserves in England have never been known to mingle. Tame rabbits which had run wild on the island of Porto Santo were kept in a zoological garden and would not mate with any of the tame breeds. The dovecote pigeon seems to have an actual aversion towards the several fancy breeds, and it has been observed that flocks of white and common Chinese geese keep distinct.

The elaborate devices which plants have developed to induce insects to transfer pollen from one flower to another and many other intricate ways in which cross-pollination is brought about make it seem that germinal mixing is favored in these organisms. The phenomenon of self-sterility is also widespread in plant families. Fruit growers have long contended with the failure of many cultivated varieties to set fruit when none but their own pollen is available. They have been forced by costly experience to make careful selection of varieties that are suitable pollinators for each other and in some cases have to grow less desirable kinds solely because they are necessary to insure proper pollination and abundant fruit setting. At the John Innes Horticultural Institute in England there have been grown apple, cherry and plum trees which bloomed freely over the entire tree, yet only certain branches produced fruit, those that were pollinated artificially with compatible varieties. The other branches on the same trees were self-pollinated and were entirely bare of fruit.

These facts have led biologists to believe that outcrossing is the natural state of affairs in plants, and have persuaded them that this was physiologically necessary to maintain normal vigor. Recent experiments at the Connecticut Agricultural Experiment Station and elsewhere have shown clearly that in several species of plants there is a clear-cut tendency in the opposite direction—that among different varieties each type is fertilized more readily by its own kind of pollen than by pollen from any other variety.

This was discovered largely by accident. In an experiment to test the immediate effect of cross-pollination upon the chemical composition of the seeds of corn it was desired to have self-pollinated seeds produced upon the same plants. To do this, pollen from two different types of plants was mixed and applied to the protected flowers of both lots of plants which produced the pollen. Advantage was taken of inherited seed characters which differentiated very clearly the self-fertilized and cross-fertilized grains.

In carrying out an experiment of this kind pollen from a variety of corn having yellow, wrinkled seeds was mixed with pollen from a variety having white, smooth seeds. Equal quantities of pollen were taken from each type of plant, placed in a paper bag and thoroughly mixed by shaking. This mixture was applied to the pistillate flowers of both types of plants which had been protected from all other pollen. When mature the self-fertilized and cross-fertilized seeds were quite distinct on each lot of plants, owing to the phenomenon of dominance of yellow over white color and smooth over wrinkled texture. On the yellow, wrinkled variety the cross-fertilized smooth seeds showed up very plainly among the wrinkled self-fertilized seeds. On the white, smooth-seeded variety the cross-fertilized seeds were yellow.

By using these and other characters which clearly indicate the source of the pollen, data were obtained which include

counts of nearly one hundred thousand individuals. From these figures the surprising superiority of self-pollination stood out clearly. In some mixtures less than two per cent. of the seeds produced were cross-fertilized, whereas with random fertilization fifty per cent. on the average should be of that type. This same result has been obtained from several species widely separated in the plant kingdom and proves that where differences exist more offspring result from the plant's own kind of pollen than from that of any other source, even though the differences are small and only in apparently minor qualities. This is true notwithstanding the fact that these same plants are perfectly fertile when the different kinds of pollen are not in competition.

Although bizarre and astonishing plant hybrids are regularly recorded in the newspapers, horticulturists are fully aware that only closely related species are fertile when interpollinated and that crossing different species seldom produces good seed. When plants are grown from such hybrid seed they are rarely fertile. Plants are as restricted in reproduction as are animals, and even in those cases, previously mentioned, where self-fertilization is reduced or prevented, it is probable that crossing within is favored rather than crossing out of the type.

With this evidence from the corners of the phylogenetic triangle—seed plants, protozoa and man—that there is a definite tendency to establish a caste system throughout nature, why should we apologize for our pride of race and of family? Is it not rather something to be fostered and maintained? Restricted marriages are customary in nearly all social groups and many savage tribes have very strict taboos against marrying out of the clan.

In India the caste system has reached its most extreme development. The members of each occupational group are forbidden to marry into any other group. Farmers can not marry the daughters of shopkeepers. The families of school teachers, bankers and manufacturers are each limited in their choice of husband and wife to the members of their own trade. It is not apparent how such artificial barriers can work to the best interests of the race, and it seems that an over-refinement, bordering on absurdity, has been reached in that country.

This should not obscure the fact that the ability to retain superiority when once established is a primary necessity in racial progress and the mating of like with like is a natural law too deep-seated and too well established to be set aside by political systems.

The practice in this country is much more sound, biologically. Marriage is as severely restricted to members of the same social level as in any other country, but individuals change from one level to another according to their ability to demonstrate their true worth. There are many exceptions to this, of course, but the general tendency is plain. Owing to inherited wealth and its accompanying social advantages the weeding-out process is not so effective as might be desired. The inheritance tax has eugenic significance. But even under the present system, wealth vanishes unless accompanied by intellectual integrity, while titles remain to embarrass those forms of government which still cherish them.

Concern is often expressed lest legal barriers be removed and marriages between different races be encouraged, as if statutes were the only preventive of miscegenation! Authorities disagree as to the harm and benefits of race-crossing. Some say that the mating of racially different individuals of equivalent social standing is not so serious as the lowering of the standards of social groups within the race. Nature does not argue this point, but guards against both by a system of marital selection the foundations for which were laid in the lower forms of life and which has evolved with man himself.

GARA CHEURFA

By ALONZO W. POND

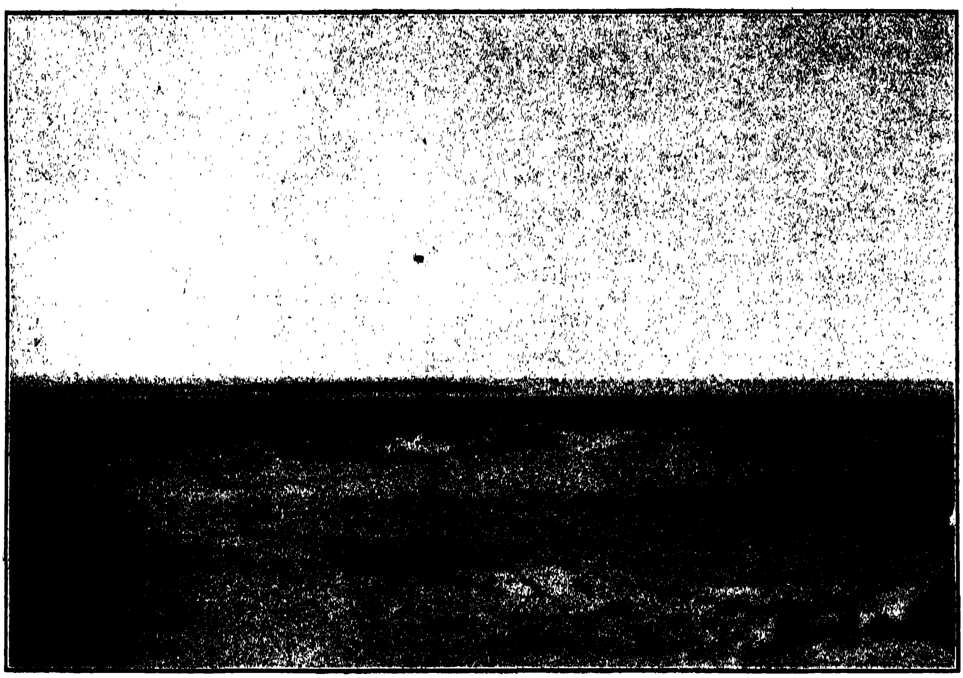
ASSISTANT CURATOR LOGAN MUSEUM, LEADER LOGAN–SAHARA EXPEDITION, 1925 CAMPAIGN

THE desert traveler from the north and northeast descends from the plateau of Tademait, taking as his guide a table mountain, on the western end of which he sees a pile of stones, a signal cairn for weary caravans which marks the direction of the Arab village Aoulef Cheurfa, three days by camel west of InSalah, in the Sahara Desert. For the geologist that signal rock is just one of the isolated remnants of the Tademait plateau which he will tell you is composed of very hard sandstone formed millions of years ago. Millions of years have worked their changes out here in the Sahara, and ancient rivers, sand-laden winds and extreme changes in temperature have cut away much of the great plateau, leaving here and there isolated remnants, steep-sloped mountains which stand like great stone monuments of forgotten ages. The Arab name for these steep-sided remnants of ancient plateaus is Gara, and the Gara which marks the direction of the village of the Cheurfa tribe is called the Gara Cheurfa.

In the depression west of the flat-topped mountain the Cheurfa have planted their date palms, which they irrigate with water carried by long tunnels from the plain to the west. Their tunnels are dug in the clay at the water level and slope toward their palm groves so that the water which has fallen in the mountains hundreds of miles to the north is here collected and carried in artificial channels until it reaches the surface in the depressions and can be used to water palm trees and garden beds of wheat and vegetables. Great dunes of sand on the north and east of the palm grove protect it from the cold winds and constantly threaten to bury the oasis.

Seven centuries the Cheurfa have lived in the shadow of the Gara Cheurfa, for historic records give their arrival from Morocco and the founding of the village Aoulef Cheurfa in the latter half

GARA CHEURFA SEEN FROM THE DISTANCE.



AOULEF CHEURFA, OASIS AND VILLAGE SEEN FROM THE GARA.

of the thirteenth century. Perhaps it was those first arrivals from Morocco who found fresh water in the crevice just below the summit of the eastern end of the Gara and called that water hole "Mother of People Spring" because it supplies drink to the desert traveler who passes that way. Natives tell us that the "spring" has long been dry and scientists smile, saying, "Because it is a long, long time since it has rained here. Your spring is just a natural cistern." The summit of the Gara slopes east, so that whatever rain falls must collect in any depression at the eastern end of the mountain; as this hollow is covered with big rocks it is protected from evaporation and water stands there for many weeks.

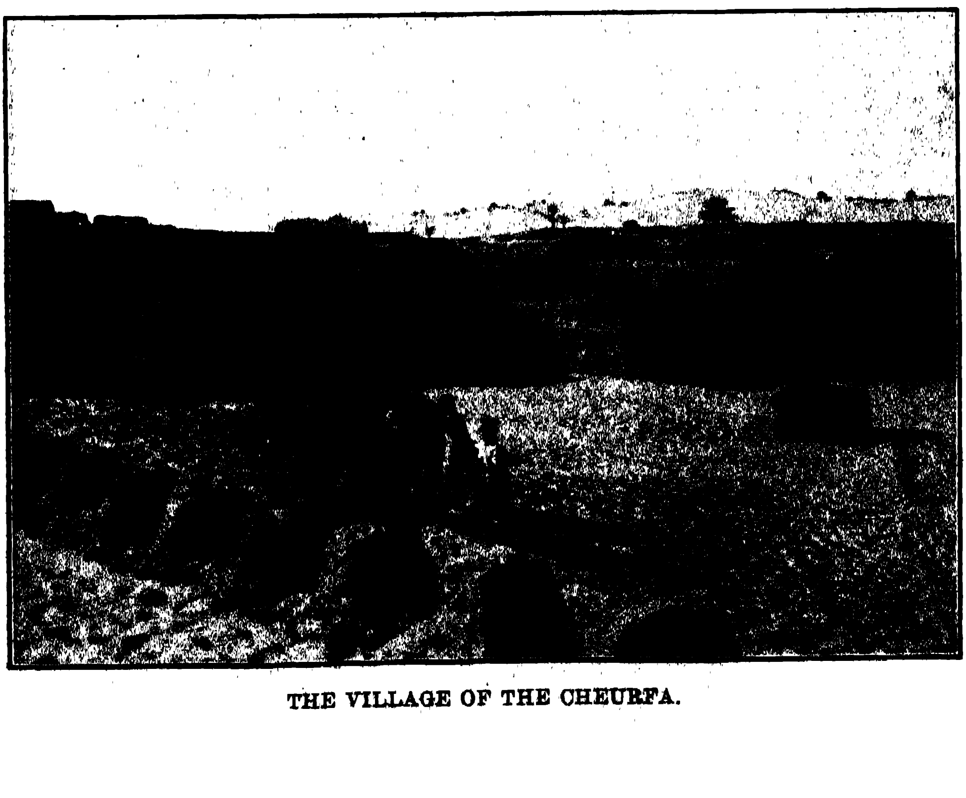
We know that Gara Cheurfa was a meeting place of more ancient peoples than the thirteenth century Cheurfa, for on the western slope gigantic blocks of the hard sandstone, broken off from the mountain, are covered with inscriptions in tifinar characters, the writing of the ancient Libyans and of the modern Tuaregs. Here and there among the inscriptions are carved crude camels and cruder representations of men. In 1903 these inscriptions were copied and translated by a French officer, so we know their significance, a meeting place for the Tuaregs long before the arrival of the Arabs from Morocco.

In recent years it has served as a place for religious gatherings. A Marabout or priest, who the natives tell us "came from another village," frequently summoned the people living in the vicinity of the Gara to prayer. A long trench, still visible, served as the line at which the crowd assembled before the priest and prayed.

There are mysteries about the flat-topped mountain that overlooks the village of Aoulef, for on rare occasions the inhabitants say, "the mountain fires a

gun." The year that the French captured InSalah the villagers heard the noise of the cannon coming from the Gara, and this year in October the same report was heard. "It is the spirits of the earth who shoot," is the simple explanation of the Arabs, but science names the spirits *heat* and *cold*. All around the Gara are great blocks of stone broken from the mountain. Some have fallen down the slope and others only slipped a foot or so, leaving straight-sided fissures which are so regular that they must be artificial. The constant expansion and contraction of the rocks caused by the extremely hot days and extremely cold nights eventually splits off pieces. Although such splitting probably happens often it is only on rare occasions, when the variations of temperature are exceptionally extreme and a huge block of rock breaks away, that the noise is loud like the report of a cannon. Some of these great blocks are so placed or their composition is somewhat different so that when they are struck with another stone or club they ring like a well-cast bell. On fête days the natives frequently add the ring of Gara Cheurfa rocks to the rumble of their palm trunk drums to call the crowd to feast and play.

How the spirits of that ancient rock must smile and chuckle at the efforts of the people who live in its shadow and of us who have traveled thousands of miles to learn its secrets! Some of the secrets of the Gara we can read to-day as easily as we read the daily paper, but unfortunately the date of publication and the name of the editor as well as his nationality seems to remain a secret of the Gara spirits. The secrets we read are told us by the stone implements found by the Logan Sahara Expedition of Beloit College on a plain a mile east of the Gara Cheurfa. This plain the geologists tell us (Professor E. Gautier, Uni-



THE VILLAGE OF THE CHEURFA.

versity of Algiers) is a quaternary formation. Thousands of years ago water, probably as a river, cut its way down through that ancient plateau of Tademait. When the Sahara dried up, the winds got their clear sweep across the plain, and they carried all the loose sand away to pile it up as dunes in the lower depressions and left only a hard-packed sandy clay plain which geologists call a reg. The gravel stones which had been rolled by the water could not be blown away with the sand and rest on the surface of the reg. For thousands of years the sand-laden winds have cut and polished these pebbles so that it is not uncommon to find some worn flat on the side exposed to the weather.

It is in this quaternary reg six inches below the surface and four above bedrock that the expedition found fifteen coarse, heavy stone picks. In shape they are long, narrow triangles with thick rounded bases. The edges are slightly wavy, like the fist hatchets found in European paleolithic stations of the late Chellean or early Acheulian

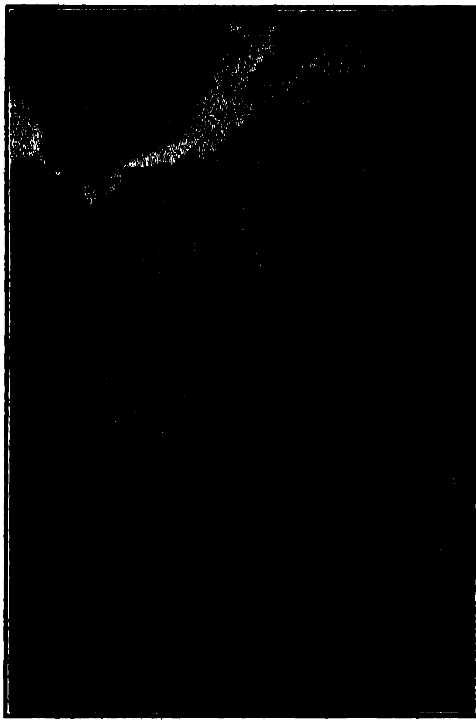
MOHAMMED DESCENDS FROM THE GARA WITH A LOAD OF SPECIMENS.

IRRIGATING TUNNEL EMPTIES ITS WATER INTO THE PALM GROVE.

period. But in Europe these deposits also contain animal remains, the bones of extinct animals which permit the scientist to know something of the climate which existed at the time the deposits were made and with that information to form a fairly definite idea of what part of the geologic epoch they belong in. In this little station near Gara Cheurfa there is not a trace of animal remains, not a hint of a hearth, nor a sign of any other ancient industry, above or below. There is only the form of the implements, but fortunately that is typical. The material of which they are made is coarse and they are covered with a heavy crust which thousands of years laying in sand and clay has added since the people who made them lived. No flakes of that coarse sandstone material were found in the deposit, nothing but the few picks or fist hatchets and these were not close

enough together to be considered as an intentionally hidden lot or cache. Not a single one of the bits of other rock found in the same trenches showed any sign of having been worked by man nor did they have the slightest semblance of definite intentional form. The bedrock formation above which the implements were found adds interest but gives no clew to the exact age of the pieces. Who made the picks found in this isolated part of the desert, a mile from the faintly traced ancient river bed and a mile from the Gara?

There is a strong probability that the descendants of the beings who made these crude picks were to be found in the region for many hundreds of generations. On the summit of the Gara, scattered over the surface at the west end, the expedition found pieces of the hard sandstone which showed evidence of having been shaped by an intelligent being. We spent many hours searching the top of that table mountain and collected about three hundred pounds of stones which have served as tools to prehistoric peoples, among them three large disks which are the cores left after the flakes have been struck off for making smaller implements and which themselves have probably served as cleavers. Smaller disks of which we found several, may have served as scrapers, and three which were found together in a trench about eight inches below the surface have been chipped in the same manner. Each has the same peculiar hollow at one side. These, however, are not made of the coarse sandstone but of petrified wood and are so regular and uniform that it leads us to think that the prehistoric people who made them wrapped them in bits of skin and with a short leather thong attached them to a long leather rope and used the contraption to catch animals with much as the South Americans use a three-balled bolo. Whirling the rope with its three heavy ends around their head they let it fly at the feet of the running animal. The three weighted ends wrap around the legs of the beast and either stops him or hinders his progress so that the hunter is able to capture and kill him. Whether the ancient inhabitants of Gara Cheurfa used such a weapon or not we can not be certain, but finding three stones exactly alike and all obviously shaped by man permits interesting speculation on that point at least.



ANCIENT WRITING ON THE ROCKS OF GARA CHEURFA. NOTE SPLIT CAUSED BY HEAT AND COLD.

There are flat-sided points, coarse and rather thick at times, but all show artificial chipping on the edges which gives them their intended shape. A few hard pebbles of material entirely different from the formation of the Gara and which have been brought from the plain below show the battered edges character-

istic of stones which have been used to break up other rocks with—hammer stones, we call them. But perhaps the most interesting are the number of triangular picks or hatchets with rounded bases. These are much more regular in form and the flaking on the edges much finer so that the edges are straight and not wavy. They are of the same material as the picks found down on the plain and which from their form and the technique of their manufacture we believe belong to the early part of the Old Stone Age or more particularly Chellean or early Acheulean period of archeology, made of the same material and similar in shape but showing much finer technique and skill in workmanship. Are they simply a later product, later by many thousands of years, it is true, but a product of the same race of people who made the coarser implements found only a mile away?

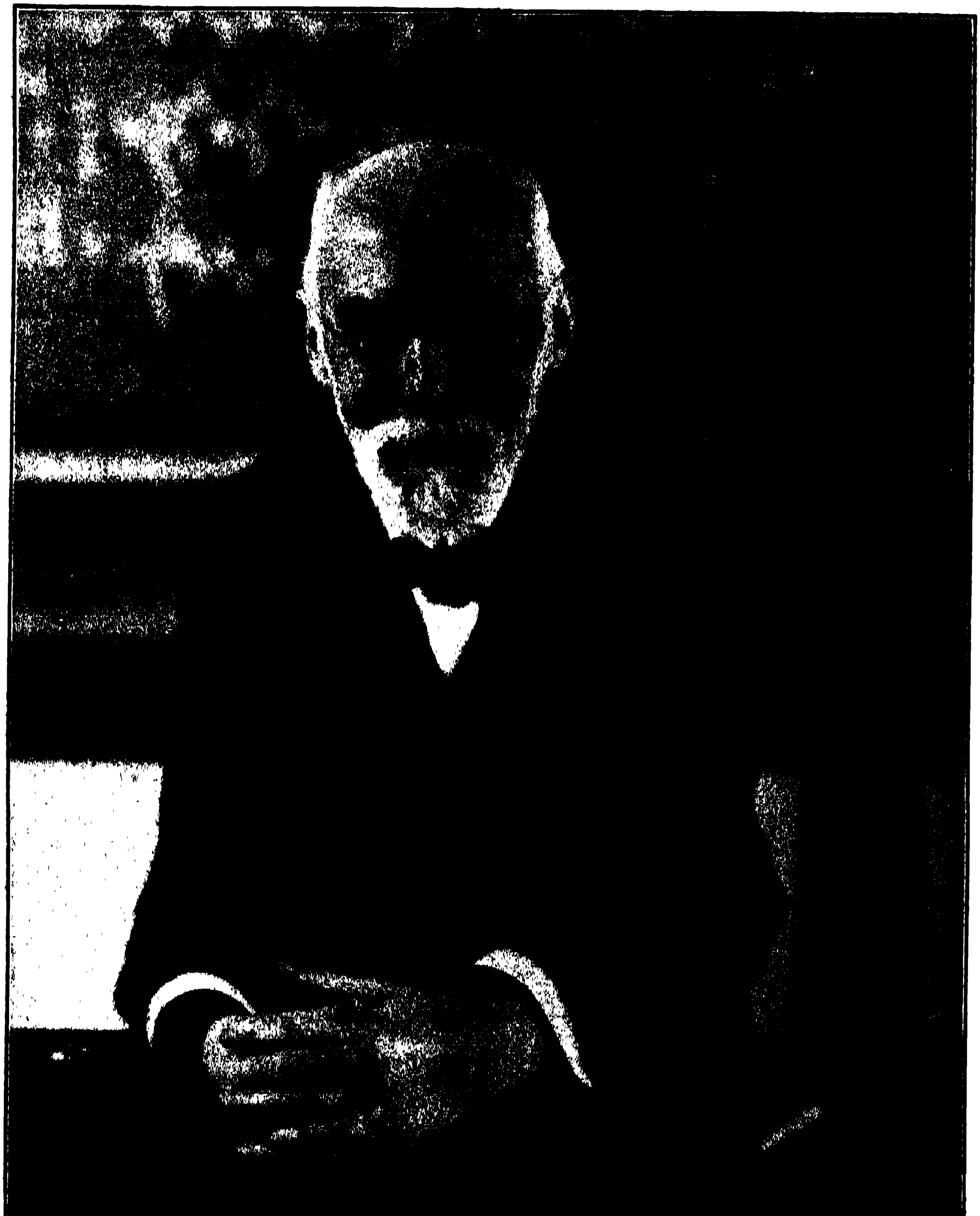
In Europe we have found many of the flat-sided scrapers and points, some of which were probably used as spear points, and with them the same sort of disks and even the small identical "bolo" stones; but in Europe the deposits in which they are found also contain the remains of feasts and fireplaces so that the industry has been carefully studied and its place in the world's progress well established. In Europe no one would hesitate to say that these worked stones belonged to the Mousterian period of the Old Stone Age, but here in the Sahara we have no animal remains to help us identify the age of the implements, and in the same deposit with the characteristic Mousterian pieces we find the fist hatchets which are typical of the late Acheulean culture. Perhaps the people who lived on Gara Cheurfa a hundred thousand years ago (unfortunately there is absolutely nothing by which we can date the industry even as to its place in geological periods) were the descendants of those who made the cruder hatchets of the plain, and we

MOTHER OF PEOPLE SPRING ON GARA CHEURFA.

NEGRO CITIZENS OF AOULEF CHEURFA CARRYING DATES.

might call their industry a Mousterian culture with Acheulean tradition. What is the relation of this industry in the heart of the Sahara Desert to similar techniques in Europe? The forms of implements found on the two continents are so similar that one recognizes the characteristics at once. Perhaps further study and other discoveries will answer the question for us.

If we can not date the industry of Gara Cheurfa we have at least discovered that at some time in the distant past a people lived here in the Sahara who made flat-sided spear points, disk-like cleavers and small throwing stones very much like the people who lived in Southern Europe a hundred thousand years ago . . . the Mousterians and the late Acheuleans What became of those people? Did their descendants migrate to the north and south? Did they remain in the region or did they just die off gradually? Those are some of the questions the spirits of Gara Cheurfa could answer if we could understand their language and they would tell their secrets.



HENDRIK ANTOON LORENTZ

THE PROGRESS OF SCIENCE

HENDRIK ANTOON LORENTZ

AMONG the small group of physicists to whom the chief credit is due for the rapid and revolutionary advances in physical science during the last thirty years, Hendrik Antoon Lorentz, who died on February 5 at the age of seventy-six years, occupied a prominent place. He was a pioneer in the general field that is suggested when the electron is mentioned, and predicted some of the most important properties of the electron before electrons were discovered or even named. It was for work in this field that he received the Nobel prize about twenty years ago. He took a prominent part also in the discussions regarding the effect of relative motion between matter and ether and in treating the whole series of puzzling questions that were raised by the failure of the Michelson-Morley experiment to give positive evidence of such motion. It was Lorentz who showed the way in which the mass of a moving electric charge depends upon its velocity; and upon the assumption, now universally accepted, that all matter is made up of electrical charges he showed that not only the mass but also the dimensions of a moving body must depend upon its speed. Although his work was based upon the assumption of a quiet ether—now generally abandoned—it led to the same results that were afterward obtained on the basis of the theory of relativity; so that he is to be regarded as a pioneer in this field also. In fact during his long tenure of the professorship of theoretical physics at the University of Leyden he made important contributions to almost every branch of physics. At the jubilee celebration held in his honor two years ago the most distinguished physicists in Europe, many of them his former students, were present to extend to him their congratulations.

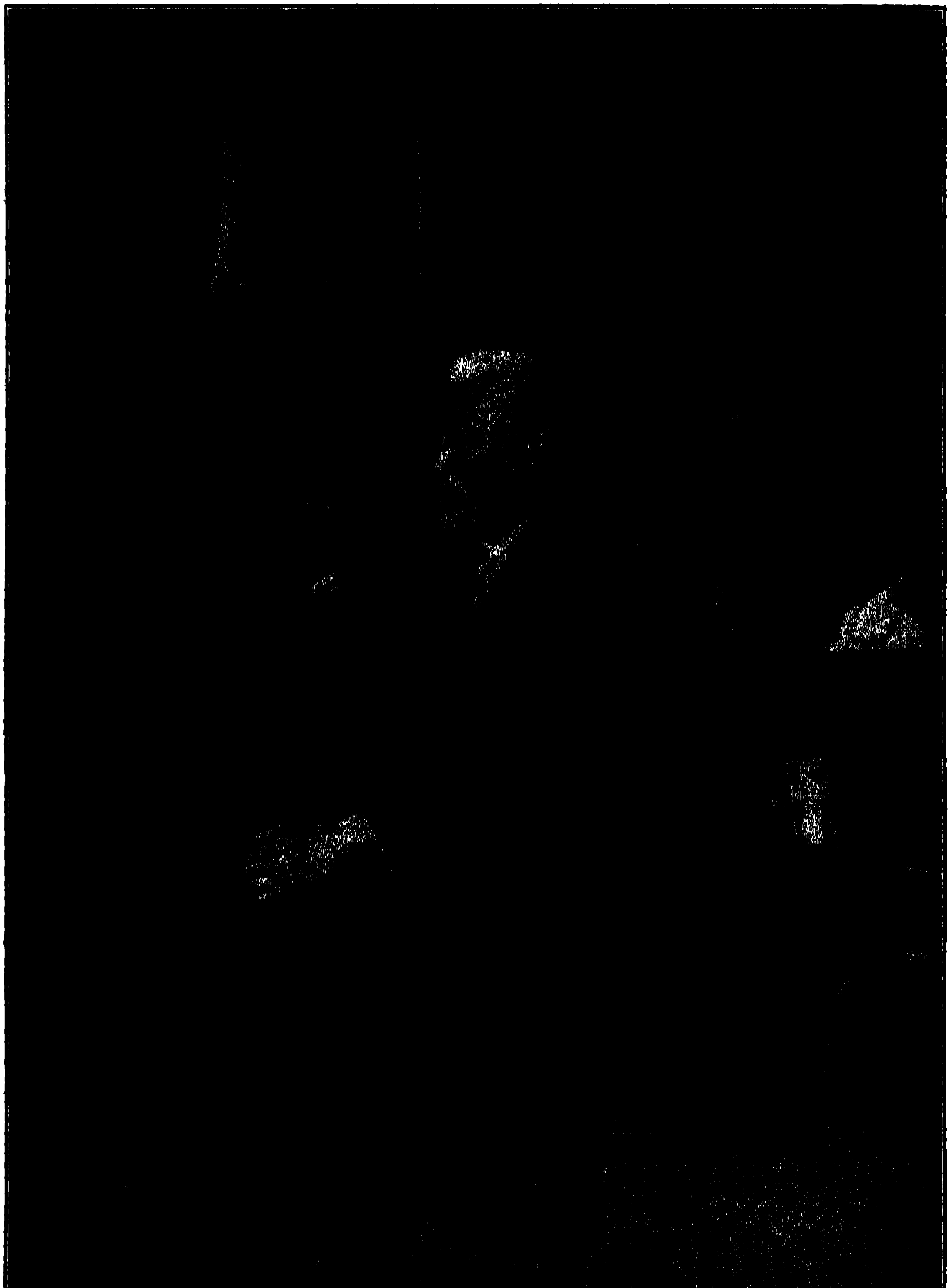
Professor Lorentz was the representative of Holland on the Committee of the League of Nations on Intellectual Cooperation and at the time of his death was chairman of this committee.

He has made several visits to this country. A series of lectures delivered at Columbia in 1906 formed the basis of a book on electron theory which is still the standard treatise on this subject. In 1920 and again in 1927 he spent the winter quarter at the California Institute of Technology. The portrait here reproduced was taken by Mr. Troy at the close of a series of thirty lectures at Cornell in 1926. Modest and unassuming, broad in his interests and activities, kindly and sympathetic in all his dealings, Professor Lorentz made a deep impression on all with whom he came in contact.

E. M.

THE REVOLUTION IN PHYSICS

SIR OLIVER LODGE delivered the Kelvin lecture to the Institution of Electrical Engineers on April 20. He said, according to a report in the London *Times*, that the revolution in physics during the present century was such that mathematical speculators were soaring up into the clouds of tensors and matrices and imaginary operators, and any number of dimensions of space. They dropped perturbing bombs, which when opened contained interesting things, more like seeds than explosives, and those that took root flourished exceedingly. The bombs of the quantum and of relativity were already rooted, accepted and cultivated, and had led to gravitational and electromagnetic extensions. The older method



PROFESSOR AIKITU TANAKADATE

IN HIS LABORATORY OF AERONAUTICS AT THE UNIVERSITY OF TOKIO

was to plant a seed quietly in the ground, so that its growth could be watched. Radioactivity was one, the electron was another, of those quiet and most fruitful seeds; the Bohr theory of the spectrum was yet another. But how to regard the Schrödinger waves was still a question; in a sense they had developed out of the quantum, but they were more revolutionary than that; while the latest Heisenberg and Dirac bombs were still, he supposed, under examination, and had still to prove their fertility.

Meanwhile wave-mechanics represented the beginning of a comprehensive theory of the ether, which must be contemplated by every one interested in physical reality. If it was a heresy to believe in the FitzGerald Contraction and other things, including the ether, as realities and not merely conventions to suit different observers, then he was a heretic. That a mathematician should be content with the Lorentz Transformation, without seeking to go behind it or interpret it physically, otherwise than from the point of view of various observers, was intelligible enough. But a physicist could not be so easily and pragmatically satisfied. The β factor in the Lorentz Transformation was not in it at first, and then it was not reciprocal. The introduction of the β factor completed the transformation, and that factor was the FitzGerald Contraction pure and simple.

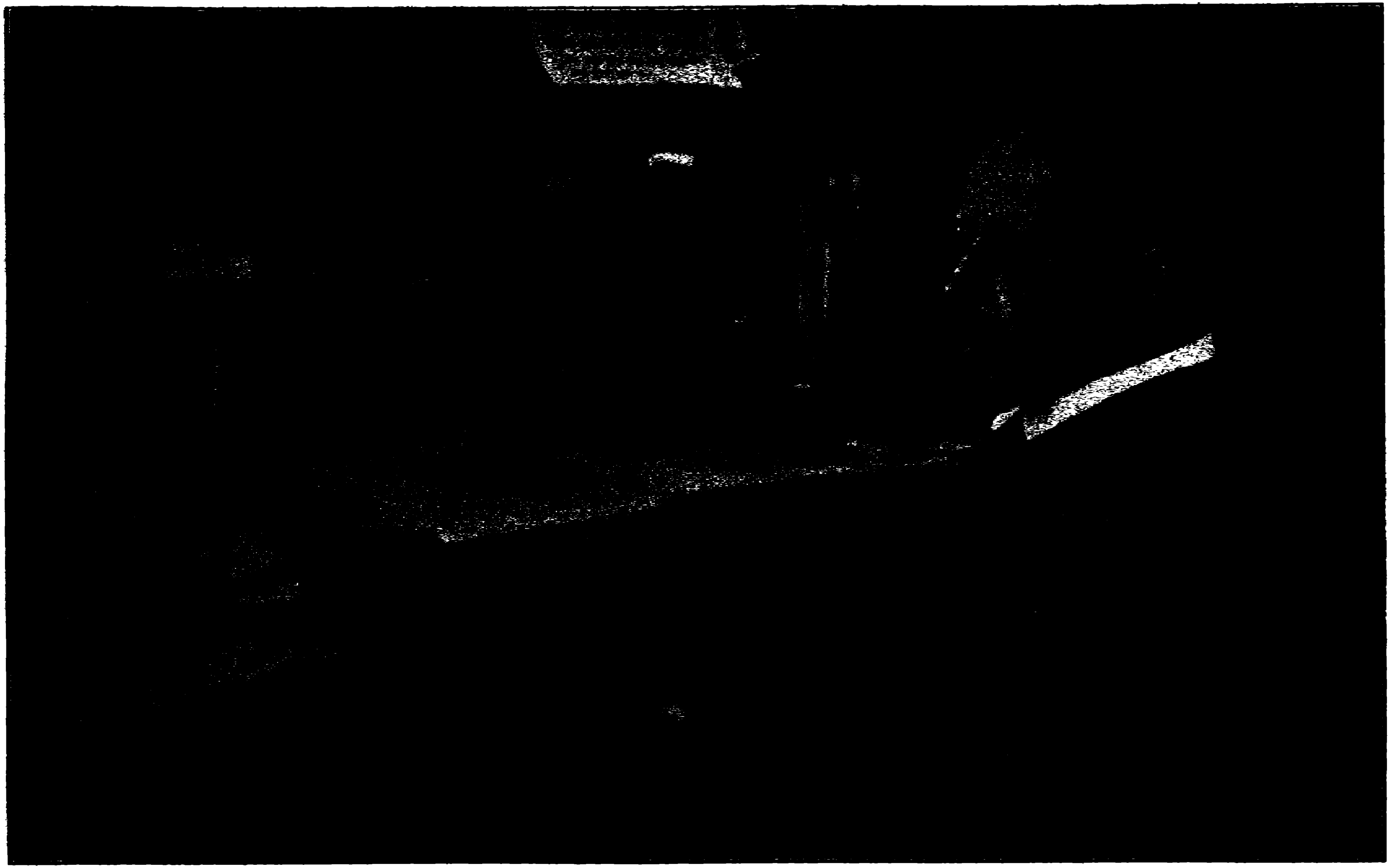
When a body radiated energy it must lose mass. It could not lose mass continuously, for mass was electric charge, and that was discontinuous. Mass could only be lost in particles, hence energy could only be radiated in quanta. Continuous radiation was impossible: it must occur in jerks. It could only be smoothed out on the average by dealing with an immense number of particles—just as gaseous or liquid pressure on the average was uniform, though really intermittent and jerky, as was shown by the Brownian movement when the bombarded surface was small enough.

There might be several different ways of regarding the same essential thing. Electric and magnetic explanations could never be ultimate so long as they could be resolved into something mechanically simpler. A vortex fluid, in which the laws of dynamics held in the innermost parts, however much they might appear departed from in the gross, was about the simplest view of the substratum of the physical universe that could be imagined, in spite of the difficulty of treating it mathematically. It would be time to try to imagine something else when that conception had been proved finally wanting or irrevocably false.

THE FOURTH INTERNATIONAL CONGRESS OF ENTOMOLOGY

The first International Congress of Entomology was held in Brussels in 1910, the second congress was held at Oxford in 1912, the third at Zurich in 1925, while the fourth is to be held in Ithaca at Cornell University during the coming summer from August 12 to 18, inclusive. Unquestionably past congresses have contributed much to the advancement of the science of entomology and to friendly intercourse among the scientists of the different countries, the influence of which has certainly contributed its mite toward a better understanding and a more mutual respect between the peoples of the different nations involved; and there seems to be no reason why the coming congress at Ithaca should not be equally effective in advancing the science of entomology and in promoting international good will.

There is every indication at the present time that the fourth congress will



DR. L. O. HOWARD
PRESIDENT OF THE FOURTH INTERNATIONAL CONGRESS OF ENTOMOLOGY.

be more largely attended than any one of the preceding congresses. This is due partly to the fact that this country and Canada have so large a number of entomologists who will be in attendance, partly to the fact that many of the foresters of this country are interested in entomology and will attend the sessions on forest insects, and partly to the fact that financial resources have been made available for aiding foreign entomologists to come to America. This latter condition assures the congress of a most satisfactory attendance by European entomologists, with especially large delegations from Britain and Germany. Of the more remote countries of the world Russia will be represented by at least six prominent scientists, China and Japan by official delegates, Australia by Dr. R. J. Tillyard, Argentina by Dr. F. Lahille, Chine by A. M. Graf, Mexico by Dr. A. Dampf, while other countries have signified their intentions of sending representatives.

The local committee, in consultation with American entomologists in various phases of the science, has formulated a tentative program based largely on the arrangement of the program of the congress in 1925 at Zurich. There will be four general forenoon sessions at which papers of broad interest will be presented by the leading entomologists of the world. The afternoons will be devoted to discussions of the following more specialized subjects: taxonomy, distribution, nomenclature, morphology, embryology, physiology, ecology, medical and veterinary entomology, genetics, economic entomology and apiculture. The great host of insect forms, their structure, relationships, remarkable transformations, habits, lives and reactions, their relation to man in carrying causative organisms of disease, their rôle in the destruction of fruits, cereals and vegetables, their injuries to domestic animals and to our great forests will be discussed from all angles in a broad comprehensive way.

The sessions for the reading of papers will be held in Baker Hall, the new chemical laboratories of the university, where lecture rooms of various capacity are available and where every facility for displaying charts and showing lantern slides is afforded. The headquarters of the congress for registration and information will be maintained in Willard Straight Hall, in which visitors will find comfortable sitting rooms, reading rooms and convenient dining rooms and cafeterias. Tea will be served here every afternoon from 4 to 5:30. The department of entomology with its lecture rooms and laboratories is situated in Roberts Hall, where visiting entomologists will be welcomed. The extensive collections of the department are also housed here and are available to any one interested.

Arrangements are being made for excursions to nearby points of scenic interest as well as to localities for collecting. A special excursion, at reduced rates, to Niagara Falls will be arranged, while plans for a trip to Pittsburgh, Philadelphia, Washington, the Japanese beetle laboratories at Moorestown, N. J., and New York, to Boston and vicinity are in process of formation.

The permanent committee of the congress is as follows: Dr. Karl Jordan, of Tring, England, permanent secretary, with Dr. Walther Horn, of Berlin-Dahlem; Dr. Y. Sjostedt, Stockholm; Dr. R. Jeannel, Paris; Dr. H. Eltringham, Oxford, and Dr. L. O. Howard, Washington, D. C., as the remaining members. All these men are planning to be present at the congress and will contribute papers. Dr. L. O. Howard, for so many years chief of the United States Bureau of Entomology, is president of the congress, while Dr. A. O. Johannsen, of Cornell University, is American executive secretary. The members of the

ROBERTS HALL

HEADQUARTERS OF THE NEW YORK STATE COLLEGE OF AGRICULTURE AT CORNELL UNIVERSITY. THE DEPARTMENT OF ENTOMOLOGY IS HOUSED IN THE CENTER BUILDING.

American Organization Committee consist of representative entomologists and include Dr. E. D. Ball, entomologist of the State Plant Board of Florida; Dr. P. P. Calvert, University of Pennsylvania; Dr. J. G. Holland, of the Carnegie Museum, Pittsburgh; Dr. F. E. Lutz, of the American Museum of Natural History; Dr. J. G. Needham, Cornell University; Professor Herbert Osborn, Ohio State University; Dr. A. W. Baker, Ontario Agricultural College, Guelph, Canada; Dr. W. H. Brittain, McDonald College, Quebec, and Mr. Arthur Gibson, Dominion entomologist of Canada.

G. W. H.

BAKER HALL

THE NEW CHEMICAL LABORATORY IN WHICH THE TECHNICAL SESSIONS OF THE CONGRESS WILL BE HELD.

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